

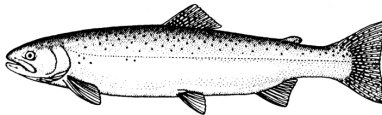
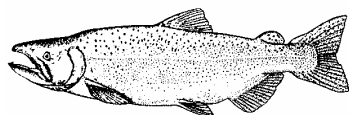
**IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR
ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY
OF CALIFORNIA AND FISHERIES INVESTIGATIONS**

**Annual Progress Report
Fiscal Year 2012**

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825



Prepared by staff of
The Restoration and Monitoring Program



PREFACE

The following is the Eleventh Annual Progress Report, Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California and Fisheries Investigations, prepared as part of the Central Valley Project Improvement Act (CVPIA) Instream Flow and Fisheries Investigations, an effort which began in October, 2001.¹ Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Wildlife (CDFW). The purposes of this investigation are: 1) to provide scientific information to the Service's CVPIA Program to be used to develop such recommendations for Central Valley streams and rivers; and 2) to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions. The purpose of this report is to provide an update on the Monitoring and Restoration Program's CVPIA-funded activities and accomplishments during the last fiscal year to interested stakeholders. An in-depth presentation on the instream flow studies is given in the final reports for these studies. The annual reports serve as final reports for the fisheries investigation tasks.

The field work described herein was conducted by Ed Ballard, Mark Gard, Rick Williams, Harry Kahler, Doug Killam, Doug Threloff and John Henderson.

Written comments or questions can be submitted to:

Mark Gard, Senior Biologist
Restoration and Monitoring Program
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

Mark_Gard@fws.gov

Electronic versions of our final reports and previous years' annual reports are available on our website:

http://www.fws.gov/sacramento/Fisheries/Instream-Flow/fisheries_instream-flow_reports.htm

¹ The scope of this program was broadened in FY 2009 to include fisheries investigations. This program is a continuation of a 7-year effort, titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

OVERVIEW

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. In 2004, Clear Creek was selected as an additional river for studies. In 2007, the Tuolumne River was selected for a minor project to quantify floodplain inundation area as a function of flow. In 2008, South Cow Creek was selected as an additional river for studies. In 2010, the Stanislaus River was selected to perform activities to assist the Bureau of Reclamation with conducting an instream flow study. The last report for the Lower American River study was completed in February 2003, the final report for the Butte Creek study was completed in September 2003, the last two reports for the Sacramento River were completed in December 2006, the final report for the Tuolumne River was completed in September 2008, the reports for the Yuba River were completed in December 2010, and the final report for the South Cow Creek study was completed in July 2011.

In 2012, the following fisheries investigation tasks were selected for study: 1) Clear Creek biovalidation – how well does IFIM compare to field observations; 2) American River gravel placement monitoring; 3) American and Sacramento River and Clear Creek redd dewatering monitoring; 4) Stanislaus River floodplain area versus flow; 5) Stanislaus River floodplain restoration project monitoring; 6) Tuolumne River Bobcat Flat monitoring; 7) Cottonwood Creek ACID (Anderson Cottonwood Irrigation District) Siphon restoration project monitoring; 8) North Fork Cottonwood Creek fish habitat assessment; 9) Yuba/Feather River sturgeon spawning habitat suitability criteria data collection; 10) Clear Creek inSALMO modeling; 11) Yuba River Hammon Bar restoration project monitoring; 12) Cottonwood Creek baseline habitat assessment; 13) Cottonwood Creek geomorphic data collection; 14) Antelope Creek geomorphic monitoring; and 15) American River screw trap site data collection.

The Clear Creek study was planned to be a 5-year effort, beginning in October 2003. The goals of the study are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There are four phases to this study based on the life stages to be studied and the number of segments delineated for Clear Creek from downstream of Whiskeytown Reservoir to the

confluence with the Sacramento River². The four phases are: 1) spawning in the upper two segments; 2) fry and juvenile rearing in the upper two segments; 3) spawning in the lower segment; and 4) fry and juvenile rearing in the lower segment. Field work for the above four phases was completed in FY 2005, FY 2007, FY 2008 and FY 2009, respectively. In FY 2007 the final report and the peer review response-to-comments document for spawning in the upper two segments was completed. In FY 2011, with funding from the CVPIA Clear Creek program, final reports and the peer and stakeholder review response-to-comments documents for rearing in the upper two segments and spawning in the lower segment were completed. In FY 2012, we completed a draft report for rearing in the lower segment and conducted peer and stakeholder reviews of this report. An additional task, preparing a document that provides a synthesis of all four reports, was added in FY 2011. We completed a draft of the synthesis report in FY 2012. The remaining work on the Clear Creek reports will be completed in FY 2013.

The Stanislaus River study activities conducted by FWS began in FY 2010 with biological validation data collection for both spawning and rearing, and initial development of hydraulic and habitat models for four sites. The hydraulic and habitat modeling was completed in FY 2012.

Work on the fisheries investigations tasks, to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions, in FY 2012 was as follows:

- 1) We completed hydraulic modeling of study site 3A on Clear Creek.
- 2) In FY 2012, with funding from the CVPIA b(13) program, we conducted modeling of the FY 2008, 2010 and 2011 gravel restoration projects on the American River and assisted with the design for the FY 2012 gravel restoration project. In FY 2013, we plan to conduct post-restoration monitoring of the FY 2012 gravel restoration project and collect data to be used for the next American River gravel project.
- 3) We conducted redd dewatering monitoring on the Sacramento and American Rivers for the CVPIA b(2) program, and determined the effectiveness of the use of b(2) water on the Sacramento and American Rivers and Clear Creek in preventing redd dewatering. This activity will not be continued in FY 2013 due to lack of funding.
- 4) We conducted the remaining phases of the Stanislaus River floodplain area versus flow task in FY 2012 with funding from AFRP³. We will complete the remaining phases of the Stanislaus River floodplain area versus flow task in FY 2013.

² There are three segments: the upper alluvial segment, the canyon segment, and the lower alluvial segment. Spring-run Chinook salmon spawn in the upper two segments, while fall-run Chinook salmon spawn in the lower segment and steelhead/rainbow trout spawn in all three segments.

³ The first phase was conducted in FY 2011 with funding from the Comprehensive Assessment and Monitoring Program.

- 5) We collected topographic data and ground-truthed LIDAR data for the Stanislaus River Knight's Ferry project and collected post-restoration data for the Stanislaus River Lancaster Road and Honolulu Bar projects. In FY 2013, we will be collecting topographic data and ground-truthing LIDAR data on the Stanislaus River Button Bush project.
- 6) We collected post-restoration data for the Tuolumne River Bobcat Flat project and started modeling pre- and post-restoration habitat to determine the quantity of fall-run Chinook salmon spawning and rearing habitat created by the Bobcat Flat project. We will be completing the modeling in FY 2013.
- 7) We collected topographic data for the ACID siphon restoration project on Cottonwood Creek to assess the effect of high flows.
- 8) We conducted an assessment of adult spring-run Chinook salmon holding habitat and upstream passage on North Fork Cottonwood Creek.
- 9) We collected habitat suitability criteria for green sturgeon spawning on the Feather River in the vicinity of the Thermalito Afterbay Outlet. This activity will be conducted for locations on the Sacramento River in FY 2013.
- 10) We provided high flow simulations to be used in the inSALMO software as applied to Clear Creek.
- 11) We collected data to model the amount of juvenile habitat created by the Yuba River Hammon Bar restoration project. We will be conducting the modeling for this effort in FY 2013.
- 12) We started collecting data to quantify the amount of juvenile habitat in Cottonwood Creek as a baseline assessment. Data collection and modeling will be completed in FY 2013.
- 13) We collected additional topographic data for the transects used in task 12 to assess topographic changes at these cross-sections.
- 14) We collected data to develop a hydraulic model of the flow split in Antelope Creek and started the modeling. We will be completing the modeling in FY 2013.
- 15) We collected depth and velocity data at a site for screw traps on the American River to be used in selecting the best location to install the traps, with funding from the Comprehensive Assessment and Monitoring Program.

The following sections summarize project activities between October 2011 and September 2012.

CLEAR CREEK

Hydraulic Model Construction and Calibration

Fall-run Chinook salmon and steelhead/rainbow trout rearing (Lower Alluvial Segment)

We completed calibration and production runs of Site 3B (the last of five rearing sites) in FY 2012. Calibration and production runs for the other four rearing sites were completed in FY 2011.

Habitat Simulation

Fall-run Chinook salmon and steelhead/rainbow trout rearing (Lower Alluvial Segment)

In FY 2012, we computed fall-run and spring-run Chinook salmon and steelhead/rainbow trout rearing habitat over a range of discharges for the five rearing sites, issued a draft report and completed peer and stakeholder reviews of the draft report. We will be issuing a final report in FY 2013.

Synthesis Report

In FY 2012, we completed a draft synthesis report. We will be issuing a final report in FY 2013.

STANISLAUS RIVER

Hydraulic Model Construction and Calibration

Fall-run Chinook salmon and steelhead/rainbow trout rearing

Construction of hydraulic models, calibration and hydraulic simulations of all sites (Two Mile Bar, Horseshoe, Valley Oak and McHenry) for a low flow range, and calibration of three out of four sites and hydraulic modeling for one site for a high flow range was conducted in FY 2010 to 2011⁴. In FY 2012, calibration was completed for the last site for the high flow range and hydraulic simulations were completed for the high flow range for the remaining three sites.

Habitat Simulation

Juvenile fall-run Chinook salmon and steelhead/rainbow trout rearing

Methods

Using the fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing HSC developed for the Yuba River, fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing habitat were computed over a range of discharges for the four rearing sites in the Stanislaus River. Habitat was computed for flows up to 1,500 cfs in FY 2011 and was computed for the remaining simulation flows up to 5,000 cfs in FY 2012.

Results

The resulting flow-habitat relationships are shown in Figure 1.

⁴ Details on the methods are given in the FY 2011 annual report and in U.S. Bureau of Reclamation (2012).

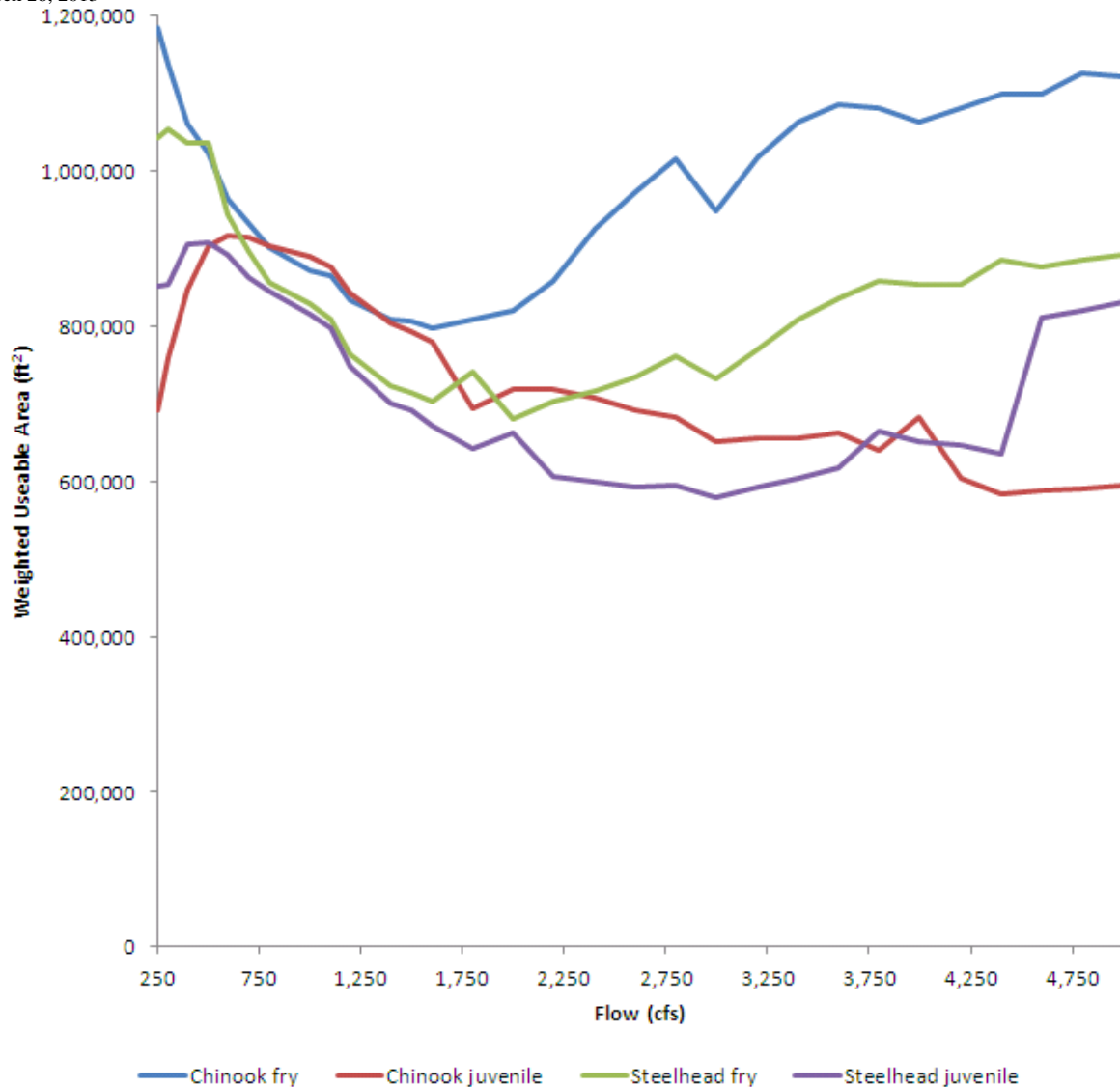


Figure 1

Stanislaus River fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing flow-habitat relationships based on River2D models and Yuba River habitat suitability criteria

Discussion

The assumptions of this study were: 1) physical habitat is the limiting factor for salmonid populations in the Stanislaus River; 2) rearing habitat quality can be characterized by depth, velocity, adjacent velocity and cover; 3) the four study sites are representative of anadromous salmonid rearing habitat in the Stanislaus River; and 4) theoretical equations of physical processes along with a description of stream bathymetry and roughness and a stage-discharge relationship provide sufficient input to simulate velocity distributions through a study site. The extent to which these assumptions were met, and thus the validity of the above results, is unknown.

FISHERIES INVESTIGATIONS

Clear Creek Biovalidation

Methods

This task had the following six subtasks: 1) compare 2008 juvenile habitat use to juvenile Combined Suitability Index (CSI); 2) compare 2005 juvenile habitat use to juvenile CSI; 3) compare 2007 Spawning Area Mapping (SAM) to adult CSI; 4) compare 2008 SAM to adult CSI; 5) after building fall-run Chinook salmon adult criteria from unoccupied locations in model, rerun earlier analysis comparing SAM and CSI; and 6) review statistical approach for these. The juvenile habitat use and spawning area mapping data were supplied by the Red Bluff Fish and Wildlife Office. Discussions during FY 2009 narrowed the scope of this work to examining data from restoration sites 3A and 3B. CSI values for site 3B will be computed from the River2D model developed for the Clear Creek IFIM study. CSI values for site 3A will be computed from a River2D model that was developed using: 1) bed topography data previously collected by Graham Matthews and Associates; 2) substrate and cover polygon mapping that the Energy Planning and Instream Flow Branch conducted in FY 2009; and 3) transect data collected by the Energy Planning and Instream Flow Branch in FY 2009.

Results

Transect and substrate and cover polygon data were completed in FY 2009. The substrate and cover polygon data were used to assign substrate, cover and bed roughness values to each of the bed topography data points previously collected by Graham Matthews and Associates. We completed hydraulic modeling for the 3A study site in FY 2012. Following the completion of the hydraulic modeling calibration and habitat simulation for the 3A and 3B study sites in FY 2012, we will be able to complete the first five subtasks in FY 2013. The sixth subtask was completed in FY 2009 by Western Ecosystems Technology, Inc. under a Cooperative Agreement funded by the Energy Planning and Instream Flow Branch. We plan to complete this entire task in FY 2013, with results to be presented in the FY 2013 annual report.

American River Gravel Placement Monitoring

Methods

The purpose of this task was to collect data to develop hydraulic and habitat models of sites where gravel was placed in the American River at Sailor Bar in 2008, above Sunrise Bridge in 2010 and 2011, and at Lower Sailor Bar in 2012. The purpose of the models is to quantify the amount of spawning and rearing habitat that was created by the restoration projects. The post-restoration topography data for the 2010 site was also used to design the 2011 gravel placement site, while the pre-restoration data for Lower Sailor Bar was used to design the 2012 gravel placement site. High flows in 2006 resulted in downcutting of the main stream river channel at the upstream end of an island downstream of the 2010 site. As a result, a side channel that used

to flow at a total American River flow of 800 cfs no longer had flow until the total American River flow reached an estimated 3,200 cfs. The 2010 and 2011 gravel placement designs consisted of both placement of spawning-sized material upstream of the island to create spawning habitat, and placement of larger material in the downcut main channel location to raise the water surface at this location, so that the side channel would once again flow at lower American River flows. We used topographic, substrate and cover data we collected in FY 2010 at the placement locations, together with the remaining topographic data collected in FY 2011, to develop pre-restoration hydraulic and habitat models to quantify how much spawning and rearing habitat was created by the 2010 gravel placement. We collected data in 2008 immediately after the construction of the 2008 site to develop a hydraulic and habitat model of this site. This model was used, together with the data collected in FY 2011 for the 2008 site and information on changes in water surface elevations at the vicinity of the 2008 site associated with construction of the 2009 gravel site (downstream of the 2008 site), to quantify the change in spawning habitat at the 2008 site associated with construction of the 2009 site and effects of high flows since construction of the 2008 site. Data is not available to model the amount of spawning habitat present at the 2008 site prior to construction; the amount of spawning habitat present prior to construction is thought to be minimal, based on aerial redd surveys prior to 2008 (John Hannon, USBR, personal communication).

A PHABSIM transect was placed at the upstream and downstream end of each study site. The downstream transect was modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect was used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the water surface elevation predicted by PHABSIM. Transect pins (headpins and tailpins) were marked on each river bank above the 7,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. Vertical benchmarks were established at each site to serve as the vertical elevations to which all elevations (streambed and water surface) were referenced. Vertical benchmarks consisted of lag bolts driven into trees. In addition, horizontal benchmarks (rebar driven into the ground) were established at each site to serve as the horizontal locations to which all horizontal locations (northings and eastings) were referenced. The precise northing and easting coordinates and vertical elevations of two horizontal benchmarks were established for each site using survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS). The elevations of these benchmarks were tied into the vertical benchmarks on our sites using differential leveling. The data collected on the upstream and downstream transect included: 1) water surface elevations (WSELs), measured to the nearest 0.01 foot (0.003 m) at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bank-full discharge surveyed to the nearest 0.1 foot (0.031 m); 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification (Tables 1 and 2) at these same locations and also where dry ground elevations were surveyed.

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 – 1
1.2	Medium Gravel	1 – 2
1.3	Medium/Large Gravel	1 – 3
2.3	Large Gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small Cobble	3 – 4
3.5	Small Cobble	3 – 5
4.6	Medium Cobble	4 – 6
6.8	Large Cobble	6 – 8
8	Large Cobble	8 – 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10 – 12

Topographic data between the upstream and downstream boundaries of the 2008, 2010, 2011 and 2012 gravel placement sites were collected using survey-grade RTK GPS units or a robotic total station and stadia rod for the dry and shallow portions of the sites, and with a combination of an Acoustic Doppler Current Profiler (ADCP) and a survey-grade RTK GPS unit for the deeper portions. For each traverse with the ADCP, the RTK GPS was used to record the horizontal location and WSEL at the starting and ending location of each traverse, while the ADCP provided depths and distances across the traverse. The WSEL of each ADCP traverse is then used together with the depths from the ADCP to determine the bed elevation of each point along the traverse. For the 2010 and 2011 sites, we used the same method downstream of the downstream boundary to determine the stage of zero flow for the downstream transect. We also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit or total station and stadia rod, and mapped in substrate and cover polygons for the areas sampled with the ADCP; the vertices of these polygons were recorded with the survey-grade RTK GPS unit. The RTK GPS and total station data had an accuracy of 0.1 foot horizontally and vertically.

Table 2
Cover Coding System

Cover Category	Cover Code
No cover	0.1
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated. The Physical Habitat Simulation (PHABSIM) transect at the outflow end of each site is calibrated to provide the water surface elevation (WSEL) at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types (Tables 1 and 2). A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by

the PHABSIM transect at the inflow end of the site⁵. The River2D model is run at the flows at which the validation data set was collected, with the output used to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

Results

In FY 2012, we completed collection of all data for the 2008, 2010 and 2011 sites and all of the pre-restoration data for the 2012 site, with the exception of some topography in the upstream extension and south bank floodplain. We completed development and calibration of hydraulic models for the 2008, 2010 and pre-restoration 2011 sites, and production runs and habitat for the 2008 site, and started production runs for the 2010 and pre-restoration 2011 sites in FY 2012. We expect to complete pre- and post-restoration hydraulic modeling for the 2010, 2011 and 2012 sites in FY 2013. Habitat for the 2008 site immediately following construction and in 2009 and 2011 is shown in Figures 2 and 3.

Discussion

The 2009 site, which raised water surface elevations at the 2008 site, had the combined effect of increasing depths and decreasing velocities in the 2008 site. As shown in Figures 2 and 3, the net effect of this change was an increase in the amount of spawning habitat at all flows for both fall-run Chinook salmon and steelhead/rainbow trout. The results of high flow (difference between 2009 and 2011 curves in Figures 2 and 3) was counterintuitive, with the amount of spawning habitat for fall-run Chinook salmon increasing at all flows and the amount of spawning habitat for steelhead/rainbow trout increasing at high flow but decreasing at low flows. Apparently, the amount of gravel moved by high flows, which reached 31,200 cfs between 2009 and 2011, was not enough to decrease the amount of spawning habitat for fall-run Chinook salmon. The amount of gravel that remained, combined with greater depths and lower velocities associated with the lowered bed elevations, was sufficient to actually increase the amount of spawning habitat for fall-run Chinook salmon. It is not surprising that high flows had a more deleterious effect on spawning habitat for steelhead/rainbow trout, versus fall-run Chinook salmon, since high flows would cause much higher rates of movement of the smaller gravel sizes used by steelhead/rainbow trout, as compared to the larger gravel sizes used by Chinook salmon. However, for high flows, the negative effect of loss of smaller gravels is less than the positive effect of reduced velocities. The peak habitat in all cases at 2,000 cfs reflects the design parameters for the Sailor Bar project, which was designed to have near-optimal depths and velocities at 2,000 cfs. The results from Sailor Bar indicate that high flows, in the magnitude of 30,000 cfs, will result in either increases in spawning habitat of up to 90 percent (fall-run Chinook salmon at 11,000 cfs), or at most a 33 percent decrease in the amount of spawning habitat (steelhead/rainbow trout at 1,000 cfs). Longer-term monitoring, after multiple high flow events, will be needed to assess the longevity of gravel addition projects on the American River.

⁵ This is the primary technique used to calibrate the River2D model.

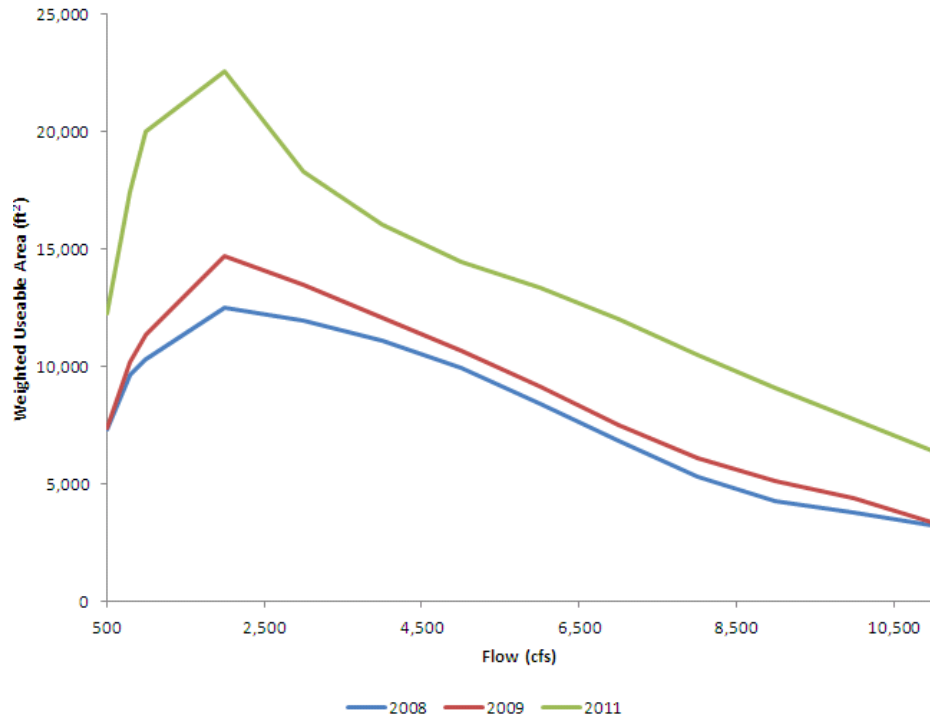


Figure 2

Sailor Bar fall-run Chinook salmon spawning flow-habitat relationships immediately after construction (2008), after construction of the 2009 site (2009), and after high flows (2011)

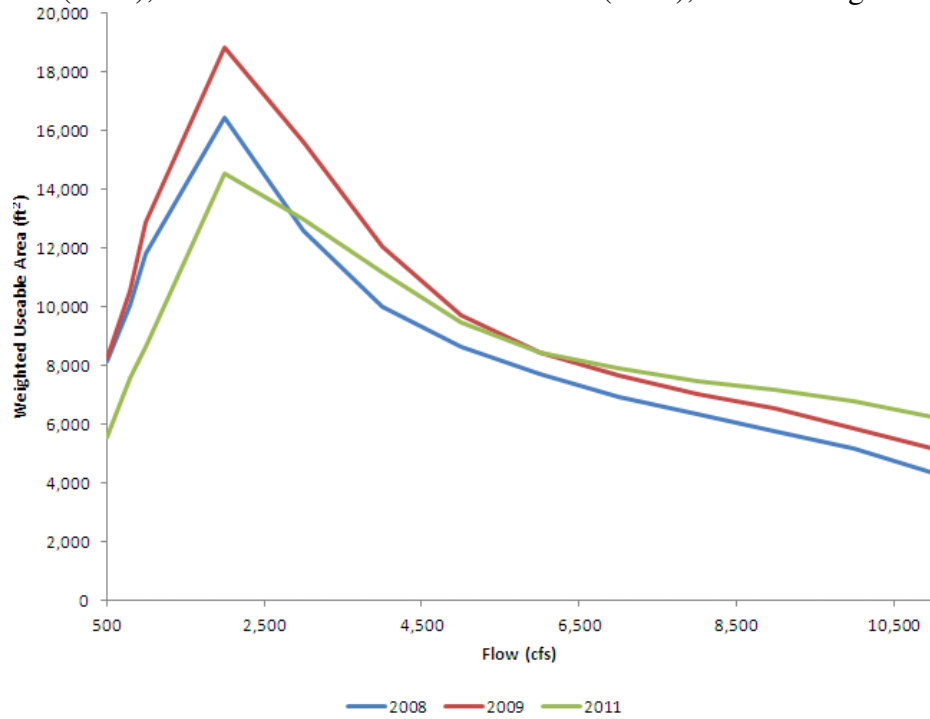


Figure 3

Sailor Bar steelhead/rainbow trout spawning flow-habitat relationships immediately after construction (2008), after construction of the 2009 site (2009), and after high flows (2011)

Sacramento and American River and Clear Creek Redd Dewatering Monitoring

Methods

The purpose of this task was to quantify the benefits of using water dedicated to fish and wildlife benefits under Section b(2) of the CVPIA to reduce dewatering of fall-run and late-fall-run Chinook salmon and steelhead/rainbow trout redds in the Sacramento and American Rivers and Clear Creek. On November 14-16, 2011, we surveyed the shallow portions of eight two-dimensional hydraulic and habitat modeling sites on the Sacramento River between Keswick Dam and Battle Creek (Figure 4), that we had developed using hydraulic and structural data that we collected in 1997 to 1999, for fall-run Chinook salmon redds. Data for redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction (Gard 1998). Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. Measurements were taken with a wading rod and a Marsh-McBirney^R model 2000 velocity meter. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. The location of each redd was recorded with a survey-grade RTK GPS unit, with the measurement taken at the center of the pit of the redd. On March 5-8, 2012, we collected the same data for late-fall-run Chinook salmon redds in our eight Sacramento River sites. On November 28 and November 30 to December 1, 2011, we collected the same data for fall-run Chinook salmon redds for five sites on the American River that we had developed using hydraulic and structural data that we collected in 1997 to 1998. On March 12-15, 2012, we collected the same data for steelhead/rainbow trout redds in our five American River sites. For both the Sacramento and American Rivers, data collected in FY 2010 were used to convert the UTM coordinates of each redd into the local coordinate system used in the hydraulic models.

For Clear Creek, the Red Bluff Fish and Wildlife Office supplied us with spawning area mapping polygons for fall-run Chinook salmon and locations for steelhead/rainbow trout redds. From this data, we used the redds located in five two-dimensional hydraulic and habitat modeling sites on the lower alluvial segment of Clear Creek, that we had developed using hydraulic and structural data that we collected in 2006 to 2007. Since we had established these sites based on State Plane coordinates, we were able to convert the redd locations to local coordinates by just subtracting given numbers from the State Plane coordinates. For the spawning area mapping, we determined how many redds were in each mapped polygon by dividing the area of the polygon by 211 ft²/redd and then equally spaced points for that many redds in each polygon, using GIS⁶.

We ran the hydraulic models for all of the study sites in all three streams at the lowest flow that would have been present if b(2) water had not been used, and plugged in the surveyed redd locations to determine what the depth and velocity would have been at each redd location at that

⁶ 211 ft²/redd was the average area of single-redd fall-run Chinook salmon polygons in 2003 on Clear Creek.

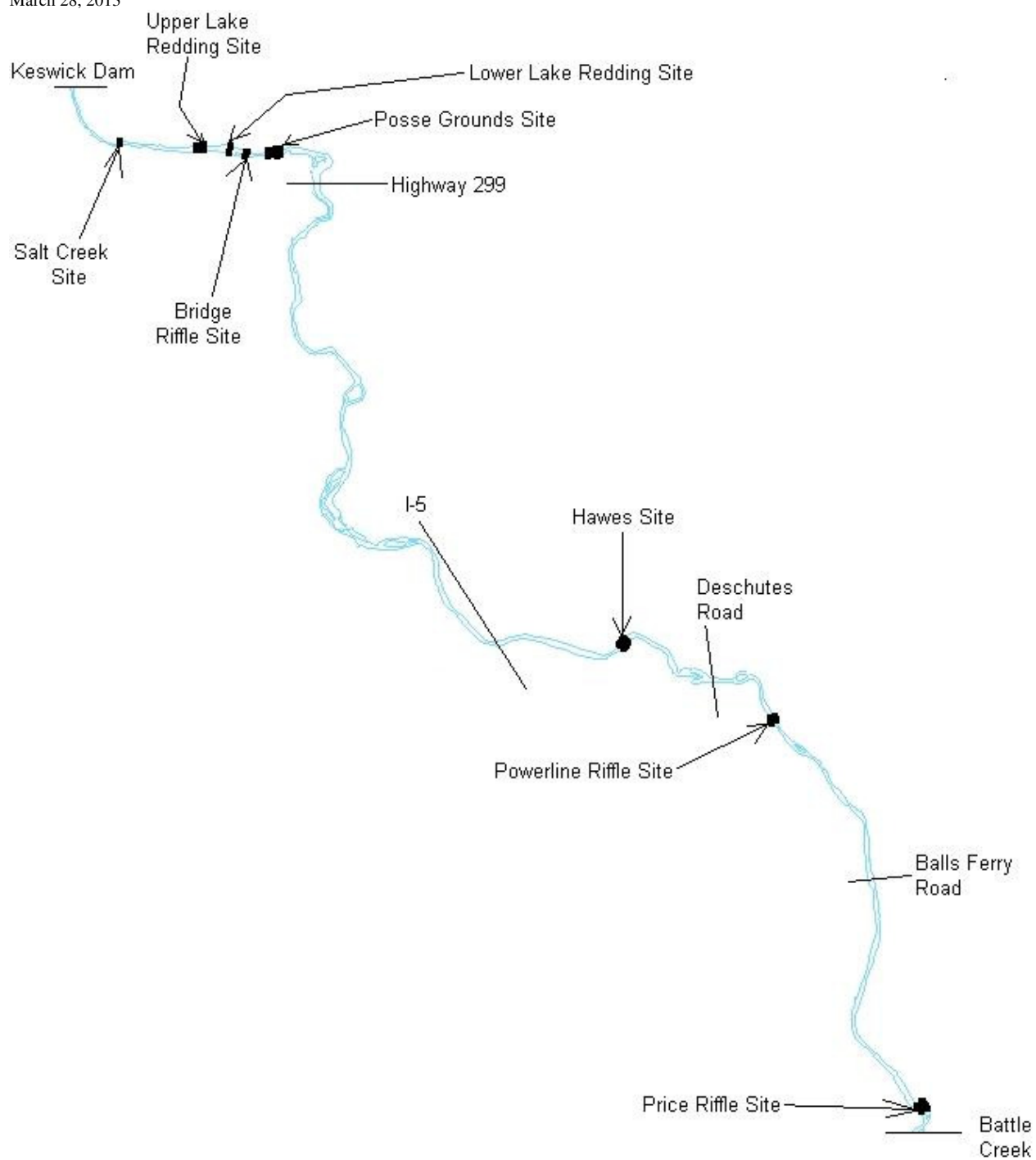


Figure 4
Sacramento River study sites for FY 2011 b(2) redd dewatering monitoring

flow. Using the criteria in Table 3⁷, we then determined how many of the redd locations would have been dewatered if b(2) water had not been used. For the Sacramento River and American River sites, we ran the hydraulic models at the flows when we collected data in FY 2010 to 2012. We compared the measured and predicted depths and velocities to evaluate to what extent the Sacramento River and American River sites have changed since we collected the data to develop the hydraulic models for these sites.

Results

For the Sacramento River, we found a total of 9 shallow fall-run Chinook salmon redds and 21 shallow late-fall-run Chinook salmon redds in our eight study sites. For the American River, we found a total of 491 shallow fall-run Chinook salmon redds and 37 shallow steelhead or late-fall-run Chinook salmon redds in our five study sites. Likely some portion of the American River steelhead redds were actually late-fall-run Chinook salmon redds, which spawn at the same time as steelhead. The only redds we were able to positively identify were those with fish on them; of these, none had late-fall-run Chinook salmon on them and one had steelhead on it⁸. For Clear Creek, there were a total of 871 fall-run Chinook salmon redds and 58 steelhead redds in our five study sites.

Figures 5 through 7 show what the Sacramento and American River and Clear Creek flows were from initiation of spawning through emergence of fry and what the flows would have been if b(2) water had not been used. For the Sacramento River, use of b(2) water potentially prevented dewatering of 0 (0%) shallow fall-run Chinook salmon redds and 7 (33%) shallow late-fall-run Chinook salmon redds. For the American River, use of b(2) water potentially prevented dewatering of 142 (29%) shallow fall-run Chinook salmon redds and 2 (5%) shallow steelhead redds. Use of b(2) water potentially prevented dewatering of 225 (26%) fall-run Chinook salmon redds and 38 (66%) steelhead redds on Clear Creek.

For the Sacramento River sites, the correlation between measured and simulated velocities was 0.37 and the median difference between measured and simulated depths was -0.2 feet. For the American River sites, the correlation between measured and simulated velocities was 0.16 and the median difference between measured and simulated depths was 0.0 feet.

⁷ A redd was considered dewatered if the depth was less than the depth in Table 3 or the velocity was less than the velocity in Table 3. The depth criteria were based on the assumption that redds would be dewatered if the tailspills were exposed, while the velocity criteria were based on the assumption that there would be insufficient intragravel flow through the redd if the velocity was less than the lowest velocity at which we found a redd. See U.S. Fish and Wildlife Service (2006).

⁸ In contrast, in FY-2010, the redds we were able to identify were almost equally split between steelhead and late-fall-run Chinook salmon.

Table 3
Dewatering Criteria

Stream	Species/Race	Depth (ft)	Velocity (ft/s)
Sacramento	Fall-run	0.5	0.32
Sacramento	Late-fall-run	0.5	0.32
American	Fall-run	0.5	0.10
American	Steelhead ⁹	0.2	0.30
Clear	Fall-run	0.5	0.10
Clear	Steelhead	0.2	0.61

Discussion

The redd dewatering monitoring proved to be an effective method to quantify the benefits of using b(2) water for reducing redd dewatering. However, the relative benefits of using b(2) water for redd dewatering, as compared to other uses of b(2) water, are difficult to estimate. Questions that still remain to be answered include how to extrapolate the monitoring results to the entire stream in question. On a qualitative level, the Sacramento River sites have not appeared to change, while several of the American River sites (Sunrise and Above Sunrise) have changed due to restoration projects and river downcutting. On a quantitative basis, the correlation between measured and simulated velocities was much less than when the data for the hydraulic models was originally collected (the velocity validations had a correlation of 0.84 for the Sacramento River sites and 0.82 for the American River sites), suggesting that there have been significant channel changes. A source of uncertainty in the American River results is the relative benefit of b(2) water for steelhead versus late-fall-run Chinook salmon; regardless, the monitoring demonstrates benefits overall to anadromous salmonids. For Clear Creek, most of the fall-run Chinook salmon redds were dewatered as a result of shallow depths, while most of the steelhead redds were dewatered as a result of low velocities, indicating that there may be different mechanisms causing egg and pre-emergent fry mortality from redd dewatering for different species. For the Sacramento River, the b(2) monitoring compliments redd dewatering

⁹ These criteria were developed for steelhead, but were applied to both steelhead and late-fall-run Chinook salmon redds, as we were unable to determine which species created most of the redds.

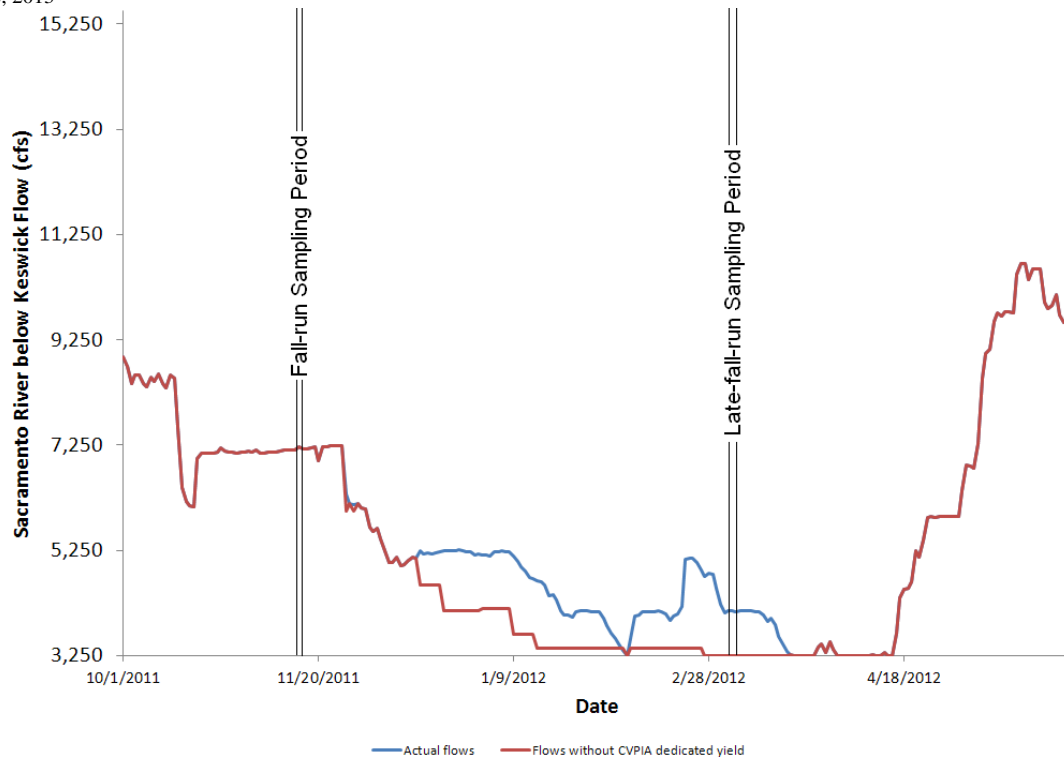


Figure 5

Sacramento River flows for FY 2012 b(2) redd dewatering monitoring

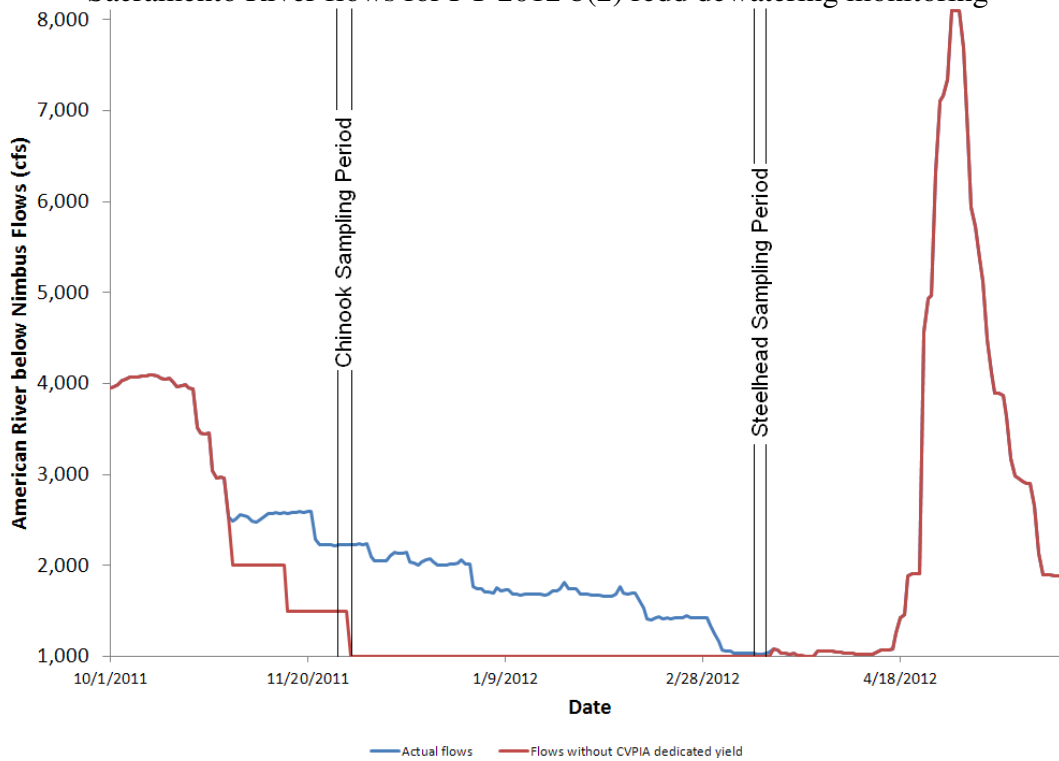


Figure 6

American River flows for FY 2012 b(2) redd dewatering monitoring

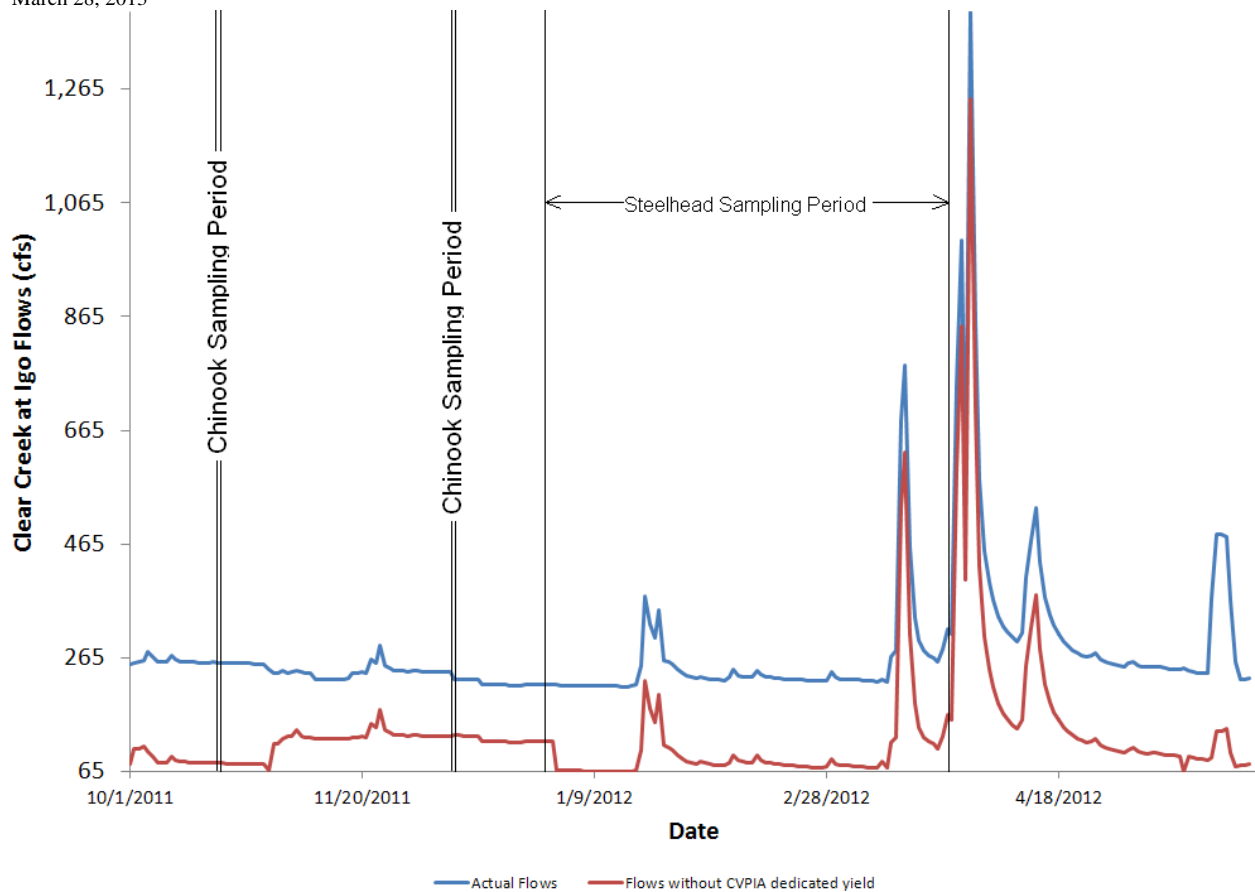


Figure 7

Clear Creek flows for FY 2012 b(2) redd dewatering monitoring

monitoring, funded by the AFRP, being conducted by the Pacific States Marine Fisheries Commission (PSMFC). The PSMFC monitoring (USFWS/CDFG/PSMFC 2011) quantifies, on a river-wide basis, the number of redds that are being dewatered as a result of actual releases from Keswick Dam, while the b(2) monitoring quantifies, for our eight study sites, how many redds would have been dewatered if b(2) water had not been used.

Stanislaus River Floodplain Versus Flow Relationships

Methods

The goal of this task was to develop two-dimensional hydraulic models to quantify the relationship between floodplain area and flow for the following four reaches of the Stanislaus River: 1) mouth of Stanislaus River to Ripon; 2) Ripon to Jacob Meyers; 3) Jacob Meyers to Orange Blossom; and 4) Orange Blossom to Knight's Ferry (Figure 8), for flows ranging from 250 to 5,000 cfs. Light Detection and Ranging (LIDAR) and Sound Navigation and Ranging (SONAR) data collected for the Stanislaus River instream flow study was used as the

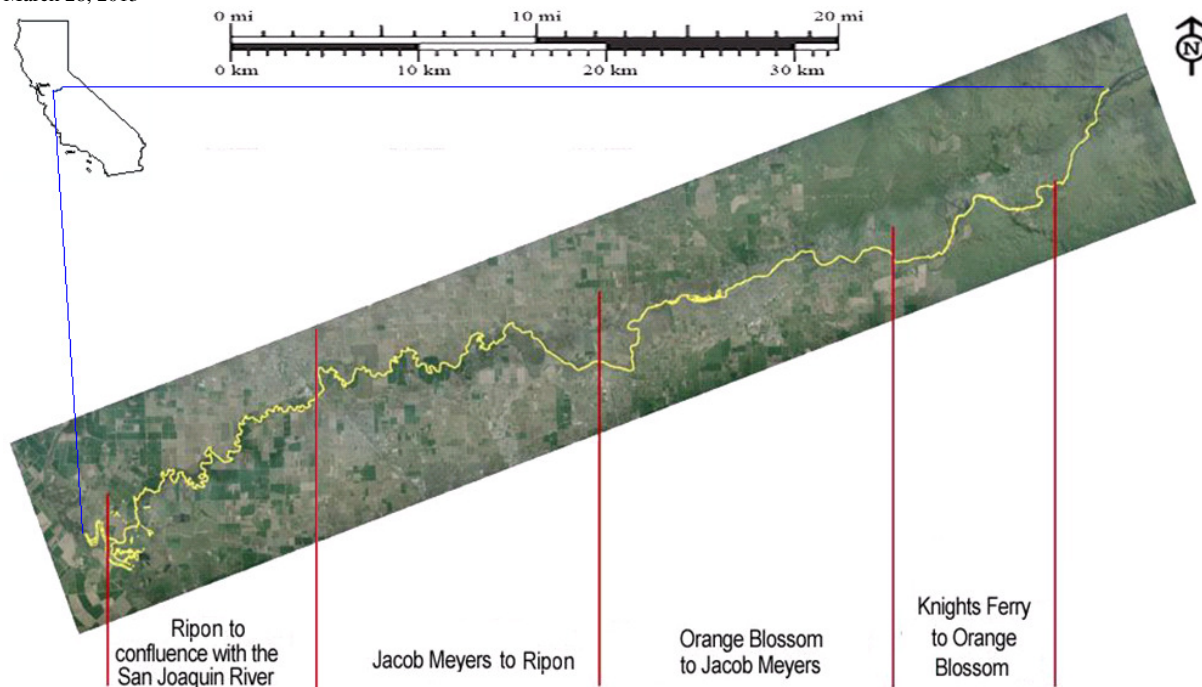


Figure 8
Reaches for Stanislaus River floodplain area versus flow modeling

topographic data source for the hydraulic model. The first step in developing the topographic input for the model was to georeference in Arc Map (ESRI, Redlands, CA) digital aerial photos of the Stanislaus River taken on January 15, 2006 at a flow of 5,000 cfs. Heads up digitizing¹⁰ was then used to produce a 5,000 cfs water's edge polygon from the georeferenced aerial photos. The polygon was used, with a 10 meter buffer, to produce shapefiles of the portion of the LIDAR and SONAR data that would be used to develop the hydraulic model. A triangular irregular network (TIN) was produced from the LIDAR data to separate the portion of the LIDAR data that was actually ground elevations (steep slopes) from the LIDAR data that was actually water surface elevations (flat slopes). The TIN was used together with NAIP imagery and heads up digitizing to produce a LIDAR water's edge polygon. LIDAR data from within the polygon, consisting of water surface elevations, was then discarded, leaving only ground elevation LIDAR data.

Comma delimited files of the resulting LIDAR and SONAR data were then produced to input into the Surface-water Modeling System (SMS, ver. 10.1.6 64 bit) software, where they were merged to create one scatter data set. A computational mesh was developed in SMS by first defining polygons based on the 5,000 cfs water's edge and LIDAR water's edge polygons. Two material types were defined for the polygons: 1) floodplain for the polygons located between the

¹⁰ Heads up digitizing refers to on-screen digitizing, an interactive process in which a map is created using previously digitized or scanned information. In heads up digitizing, the user creates the map layer appearing on the screen with the mouse, with referenced information as a background.

5,000 cfs water's edge and LIDAR water's edge polygons; and 2) channel for the polygons located within the LIDAR water's edge polygon. Patch meshes, with rectangular mesh elements 3 meters long (in the longitudinal direction) by 1 or less meters wide (in the lateral direction)¹¹, were used for the channel polygons, while 3 meter by 3 meter square paving meshes were used for the floodplain polygons. The scatter dataset was interpolated to the computational mesh using the inverse distance weighted interpolation option in SMS.

We installed pressure transducers near the mouth of the Stanislaus River to use to develop the downstream boundary condition for the hydraulic model of the mouth of Stanislaus River to Ripon reach. The data from these pressure transducers, together with stage and flow data from the Vernalis gage (USGS Gage Number 11303500), located on the San Joaquin River downstream from the mouth of the Stanislaus River, and Stanislaus River flows, were used to develop a regression equation to predict the stage at the mouth of the Stanislaus River from the Vernalis gage rating curve. The stage from the rating table of the Ripon gage (USGS Gage Number 11303000), located at the downstream boundary of the Ripon to Jacob Meyers model, was used as the downstream boundary condition for the hydraulic model of the Ripon to Jacob Meyers reach. The water surface elevation simulated at the upstream end of the Ripon to Jacob Meyers hydraulic model was used as the downstream boundary condition for the hydraulic model of the Jacob Meyers to Orange Blossom reach. We developed a modified rating table for the Orange Blossom gage (California Data Exchange Center Station ID OBB) from historical records of the stage measured at the Orange Blossom gage and the flows at the Goodwin and Ripon gages, to use as the downstream boundary condition for the hydraulic model of the Orange Blossom to Knight's Ferry reach.

The resulting computational mesh was used as an input to SRH-2D (USBR, Denver, CO), along with the above downstream boundary conditions for the hydraulic models of each reach. The hydraulic model was calibrated by running the model at 1,500 cfs and varying the Manning's n values for the channel and floodplain, with the resulting simulated water surface elevations compared to those from measurements or gage rating curve values at the following locations: 1) the Ripon gage for the mouth of Stanislaus River to Ripon reach; 2) the McHenry instream flow study site, located approximately half-way through the Ripon to Jacob Meyers reach; 3) the Orange Blossom gage and the Valley Oak site, located approximately half-way through the Jacob Meyers to Orange Blossom reach; and 4) the Horseshoe site, located approximately half-way through the Orange Blossom to Knight's Ferry reach. We used initial Manning's n values of 0.025 for the channel and 0.07 for the floodplain, based on values used by cbec Engineering for the Orange Blossom Bridge to Knight's Ferry reach (Chris Hammersmark, cbec Engineering, personal communication).

¹¹ Mesh elements one meter wide were used for wider portions of the channel while narrower elements were used for narrower portions of the channel.

The calibrated model is then used for hydraulic simulations at flows ranging from 250 to 5,000 cfs, with the above downstream boundary conditions. The model output is then processed in SMS to compute the total wetted area at each flow. The resulting total wetted area versus flow graph is then examined to determine the flow at which floodplain inundation begins, as shown by an inflection point in the graph. The total wetted area at higher flows is then subtracted from the total wetted area at which floodplain inundation begins to determine the inundated floodplain area at each flow.

Results

Calibration of the Ripon to Jacob Meyers reach indicated that the lowest Manning's n values that still resulted in a stable model were 0.025 for the channel and 0.05 for the floodplain¹²; the model crashed at lower Manning's n values. With these Manning's n values, the water surface elevations predicted at McHenry were 2.39 to 2.65 feet higher than the measured values¹³. Calibration of the Orange Blossom to Knight's Ferry reach indicated that the best Manning's n values were 0.032 for the channel and 0.07 for the floodplain. With these Manning's n values, the water surface elevations predicted at Horseshoe were 0.33 feet higher to 0.35 feet lower than the measured values. Calibration of the Jacob Meyers to Orange Blossom reach indicated that the best Manning's n values were 0.025 for the channel and 0.04 for the floodplain. With these Manning's n values, the water surface elevations predicted at Valley Oak were 0.28 to 0.32 feet higher than the measured values, while the water surface elevation predicted at the Orange Blossom gage was 0.49 feet lower than the adjusted rating curve value at 1,500 cfs.

The equation for the downstream boundary condition for the mouth of the Stanislaus River to Ripon reach is: Boundary condition = Vernalis gage height + 5.75 + 0.000329 x Stanislaus flow – 0.000273 x Vernalis flow ($R^2 = 0.88$). The Vernalis flow used in the above equation is the sum of the Stanislaus River simulation flow and 1,608 cfs, the median flow for the San Joaquin River above the Stanislaus River for the period of record of the Ripon and Vernalis gages (October 1, 1940 through April 4, 2012). The flow of the San Joaquin River above the Stanislaus River was calculated as the difference between the flows at the Vernalis and Ripon gages.

In FY 2012, we completed hydraulic simulations for the Ripon to Jacob Meyers and Orange Blossom to Knight's Ferry reaches and the computation mesh for the mouth of the Stanislaus River to Ripon reach, and started hydraulic simulations for the Jacob Meyers to Orange Blossom Reach. In FY 2013, we will complete hydraulic simulations for the Jacob Meyers to Orange Blossom Reach, and conduct the calibration and hydraulic simulations for the mouth of the Stanislaus River to Ripon reach. We will not be able to develop hydraulic models for the

¹² Typical manning's n values from the literature range from 0.04 to 0.07 (Milhous et al. 1989).

¹³ While these deviations are high, we did not have any options to reduce the deviations. Comparisons of simulated water surface elevations at 1,500 cfs to those simulated by the U.S. Bureau of Reclamation (not yet available) will serve to better evaluate the accuracy of the hydraulic model for this reach.

Goodwin Dam to Knight's Ferry Bridge reach, since SONAR data is not available for that reach. Both the Ripon to Jacob Meyers and Orange Blossom to Knight's Ferry reaches show floodplain inundation starting at 1,250 cfs (Figures 9 and 10), although the Ripon to Jacob Meyers reach has considerably more floodplain habitat than the Orange Blossom to Knight's Ferry reach.

Discussion

It is likely that the discrepancy between measured and simulated water surface elevations for the Ripon to Jacob Meyer's reach were due to a vertical datum mis-match (Rob Hilldale, US Bureau of Reclamation, personal communication). Thus, it is unlikely that any refinement to the hydraulic simulation for this reach would substantially change the relationship shown in Figure 9. The relationship between flow and inundated floodplain area, together with historical stream gage data, can be used to compute the number of acre-days of inundated floodplain for an appropriate period of each year, such as February 1 to June 15. This metric can be used in a regression analysis with juvenile survival estimates based on rotary screw trap data to understand how inundated floodplain area affects juvenile survival. The relationship can also be used in developing instream flow recommendations for outmigrant anadromous salmonids, and to prioritize areas for restoring/creating floodplain habitat.

Stanislaus River Floodplain Restoration Project Monitoring

Methods

This task involved work on the Lancaster Road, Knight's Ferry and Honolulu Bar projects. For the Lancaster Road site, the tasks were completing the collection of topography data and substrate/cover polygon data started in FY 2011, to be used by Cramer Fish Sciences to develop pre- and post-restoration two-dimensional hydraulic and habitat models of the site. For the Knight's Ferry site, the tasks were ground-truthing LIDAR data, collecting deep-water topography data, and collecting a water surface elevation profile longitudinally down the channel, with the ultimate goal of producing an integrated topographic dataset that can be used to design a floodplain restoration project at Knight's Ferry. For the Honolulu Bar project, the task was conducting an as-built survey immediately following the completion of construction of this restoration project.

For the Lancaster Road project, Cramer Fish Sciences had previously collected some topographic data, with most of the data in the southern portion of the floodplain. We used the methods described above for the American River gravel project to collect supplemental topography, substrate and cover data for Cramer Fish Sciences to use to develop pre- and post-restoration River2D models to quantify the amount of spawning and rearing habitat that was created by the Lancaster Road project. The fieldwork in FY 2012 consisted of completing the collection of topography, substrate and cover data with a total station and stadia rod in portions of the site where tree canopy prevented the use of the survey-grade RTK GPS, and conducting a control survey with the survey grade RTK GPS for locations where we had the total station set up during our topographic surveys in FY 2011.

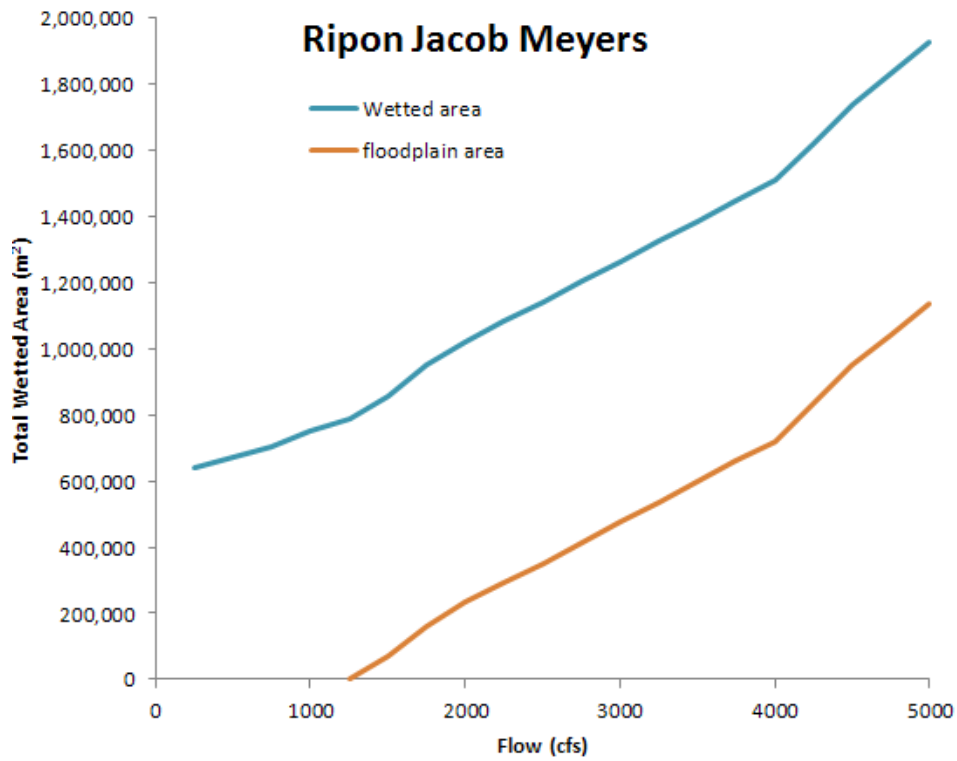


Figure 9

Floodplain versus flow relationship for the Ripon to Jacob Meyers reach

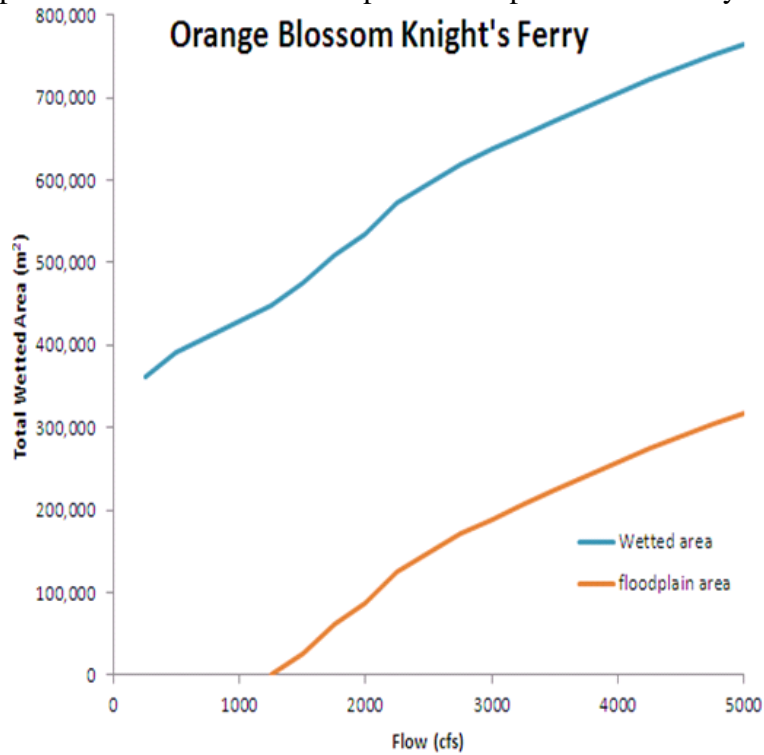


Figure 10

Floodplain versus flow relationship for the Orange Blossom to Knight's Ferry reach

For the Knight's Ferry site, there was a previous source of topographic data, a portion of the LIDAR and SONAR data discussed above for the Stanislaus River floodplain versus flow relationship task. The LIDAR data had a nominal vertical accuracy of ± 0.5 feet. We systematically selected 349 LIDAR points within the Knight's Ferry site and navigated to them with the survey grade RTK GPS; we used the stake-out feature of the RTK GPS to determine the difference between the given elevation of the LIDAR points and the elevation measured with the RTK GPS. We used a variation on the methods described above for the American River gravel project to collect bed topography in the wetted channel using our ADCP and survey grade RTK GPS, where the ADCP and survey grade RTK GPS were mounted on a six-foot one-person cataraft, which was either rowed or towed on a rope across the river to collect the topography data. The data for the survey was recorded on a laptop and RTK GPS data collector located on the shore, with the data transmitted from the ADCP to the laptop using radio modems, and the data transmitted from the RTK GPS rover to the data collector using Bluetooth. This data will be used to supplement the SONAR data and to determine if there have been changes in the channel topography since the SONAR data was collected in 2008. The water surface elevation profile was measured by collecting topography points at water's edge on both banks using the survey grade RTK GPS units.

For the Honolulu Bar project as-built survey, we used our survey grade RTK GPS units and total station to collect topography data throughout the restored channel and floodplain.

Results

For the Lancaster Road project in FY 2012, we completed collecting topographic data points. Between FY 2011 and 2012, we collected a total of 3,910 topographic data points, which Cramer Fish Sciences can use to supplement LIDAR data and the previous topographic data that Cramer Fish Science had collected.

For the Knight's Ferry project, we were able to stake out 238 of the LIDAR points; of the remaining 111 points we selected, at least seven could not be staked out because the RTK GPS stayed in float due to being under vegetation and we were not able to get to at least 27 points due to heavy brush in the way¹⁴. Of the 238 points we staked out, 225 (94.5%) had elevations within 0.5 feet of the LIDAR elevations. For the points where the difference was more than 0.5 feet, no points had groundtruthed elevations that were more than 0.5 feet higher than the LIDAR elevations, while 13 points had groundtruthed elevations that were more than 0.5 lower than the LIDAR elevations. The average difference in elevation between the LIDAR and ground-truthing elevations for the 238 points was 0.043 m. We collected 2,021 topographic data points in the wetted channel.

For the Honolulu Bar project as-built survey, we collected a total of 10,478 topographic data points. The as-built topography is shown in Figure 11.

¹⁴ The RTK GPS would likely have stayed in float at these points as well.

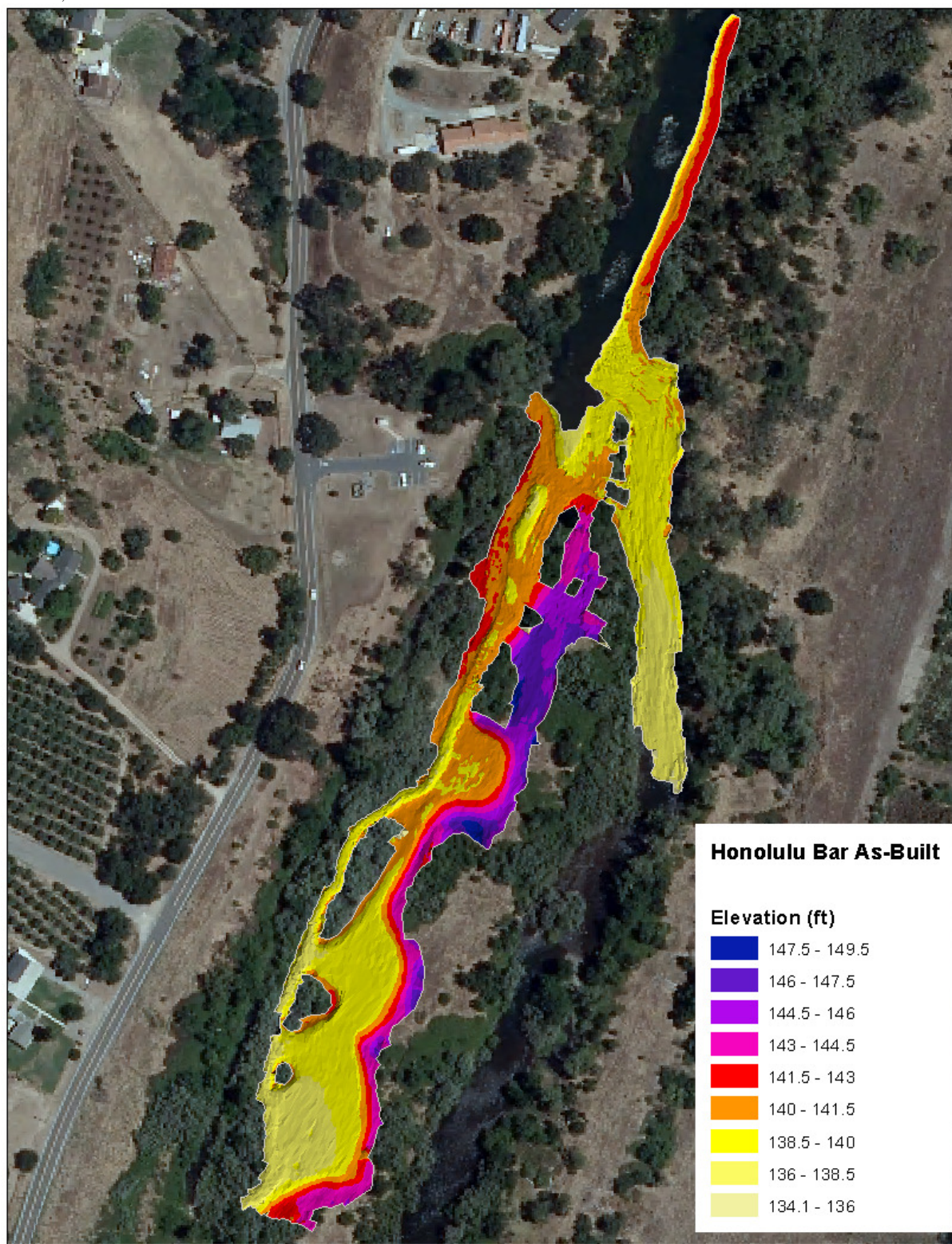


Figure 11
Honolulu Bar as-built topography

Discussion

The LIDAR data is sufficiently accurate for purposes of designing the Knight's Ferry restoration project, although less excavation than planned will likely be needed in highly vegetated areas during construction. It is likely that the elevations of the LIDAR data in highly vegetated areas are too high because the last return was off of vegetation instead of the ground. The combined dataset of topographic data from LIDAR, ADCP and SONAR should serve as a good topographic dataset for designing the Knight's Ferry restoration project. The data that we collected for the Lancaster Road project should greatly improve the accuracy of the pre- and post-restoration hydraulic and habitat models, and thus increase confidence in the quantification of habitat gained as a result of the project. The as-built topography shown in Figure 11 can be compared to the design for the Honolulu Bar to assess how close construction was to the design specifications, and to use in hydraulic modeling to assess the amount of floodplain inundation that would be expected in the project footprint at different flows.

Tuolumne River Bobcat Flat Pre and Post-restoration Monitoring

Methods

We established a 1,280 foot long pre-restoration study site that included all of the mesohabitat types (Bar Complex Run, Bar Complex Riffle, Bar Complex Pool and Flatwater Run) present in the restoration site. This study site has one downstream boundary and two upstream boundaries – one with the main river flow, and the other where a side channel enters the river. As a result, an additional data item was needed – the discharge of the side channel at three flows, to develop a flow-flow regression between the side channel and total Tuolumne River flow. We used the same methods given above for the American River to collect the remaining data needed to develop a pre-restoration hydraulic and habitat model of the Bobcat Flat site. We also collected additional data upstream of the study site, using the same methods, to supplement existing LIDAR and SONAR data, for purposes of developing an upstream extension for the hydraulic model.

The post-restoration study site coincided with the pre-restoration study site, except that the post-restoration study site extended further downstream on one bank, so that the downstream boundary of the post-restoration study site was perpendicular to the flow in the restored habitat. The data for the post-restoration study site was collected using the same methods as for the pre-restoration study site. Bed and mesh files for the pre and post-restoration study sites were developed using the same methods given above for the American River.

Results

We completed all pre and post-restoration data collection. We used a different technique in PHABSIM (MANSQ) to develop the stage-discharge relationships for the upstream and downstream boundary conditions for the pre-restoration study site, since we only have two sets of WSEL measurements to use in developing these stage-discharge relationships. We completed

the bed files and are in the process of developing the computational meshes for both the pre and post-restoration study sites. In FY 2013, we will complete the computational meshes, hydraulic calibration, and hydraulic and habitat modeling to quantify the amount of spawning and rearing habitat created by the Bobcat Flat project. Habitat modeling will use the Yuba River habitat suitability criteria discussed above. Results will be presented in the FY 2013 annual report.

Cottonwood Creek ACID Siphon Monitoring

Methods

The Cottonwood Creek ACID Siphon project involved replacing an existing siphon that created an upstream passage barrier with a new siphon that was eight feet deeper. Replacement of the siphon involved the construction of a bypass channel through a cobble bar into an old overflow channel and building a coffer dam. Due to high flows during the middle of construction, the coffer dam was washed away and the bypass channel was widened, resulting in insufficient material to fill in the bypass channel after construction. The purpose of the monitoring was to evaluate the stability of the site after construction, with particular emphasis on whether additional downcutting of Cottonwood Creek would result in the new siphon being exposed, and whether the bypass channel would capture the main flow of Cottonwood Creek, resulting in dewatering of the main channel. We collected topographic data for the Cottonwood Creek ACID Siphon project site on September 10-12, 2012 using survey-grade RTK GPS units. We compared our results with our survey in 2011 to evaluate channel changes associated with high flows in the winter and spring of 2011-12, reaching 5,072 cfs on March 28, 2012 (a 1.4% exceedance value).

Results

We collected 7,629 data points, covering approximately the same area we sampled in 2011. The topographic data are shown in Figure 12. There was both aggradation and erosion in the site (Figures 13 and 14), with a net loss of 18,661 ft³ of material from the area sampled in 2011. In general, aggradation appears to be occurring in the lower portions of the bypass channel and erosion appears to be occurring in the higher portions of the bypass channel (Figure 14). The largest decrease in bed elevation on the bypass channel thalweg reflects a shift in the location of the thalweg between 2011 and 2012, rather than erosion at a given location. As a result, the bypass thalweg elevation change seen in Figure 14 is not reflected in the data displayed in Figure 13. The erosion at the bypass channel entrance was in the bar, rather than in the main channel. Based on the thalweg profile of the main channel and bypass channel (Figure 14), it appears unlikely at this point that the bypass channel will capture the entire flow of Cottonwood Creek, nor is there evidence of continued downcutting of the main channel. At the siphon location, there has been scour in the main channel but aggradation in the bypass channel (Figure 15).

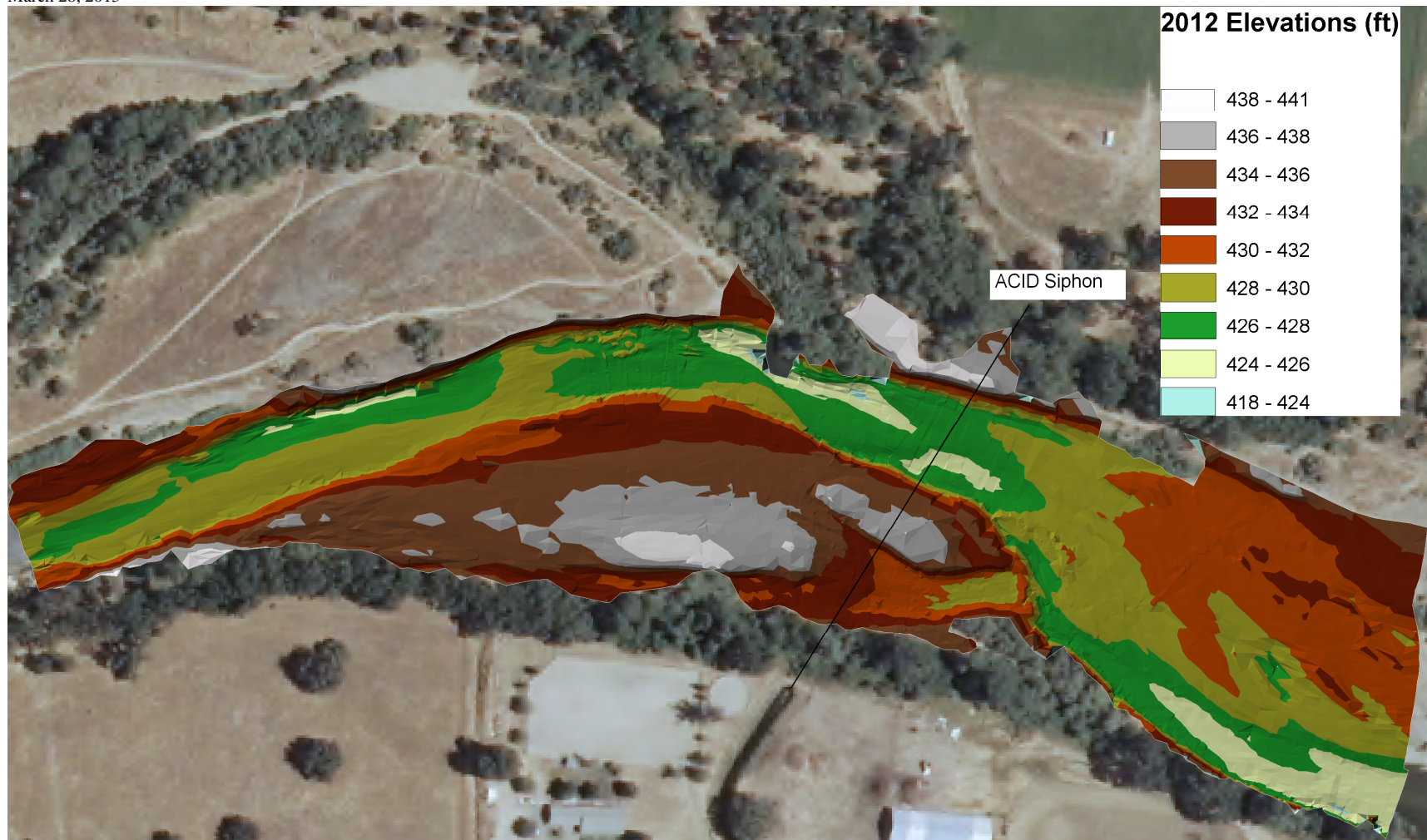


Figure 12
September 2012 bed topography of Cottonwood Creek ACID siphon restoration site.

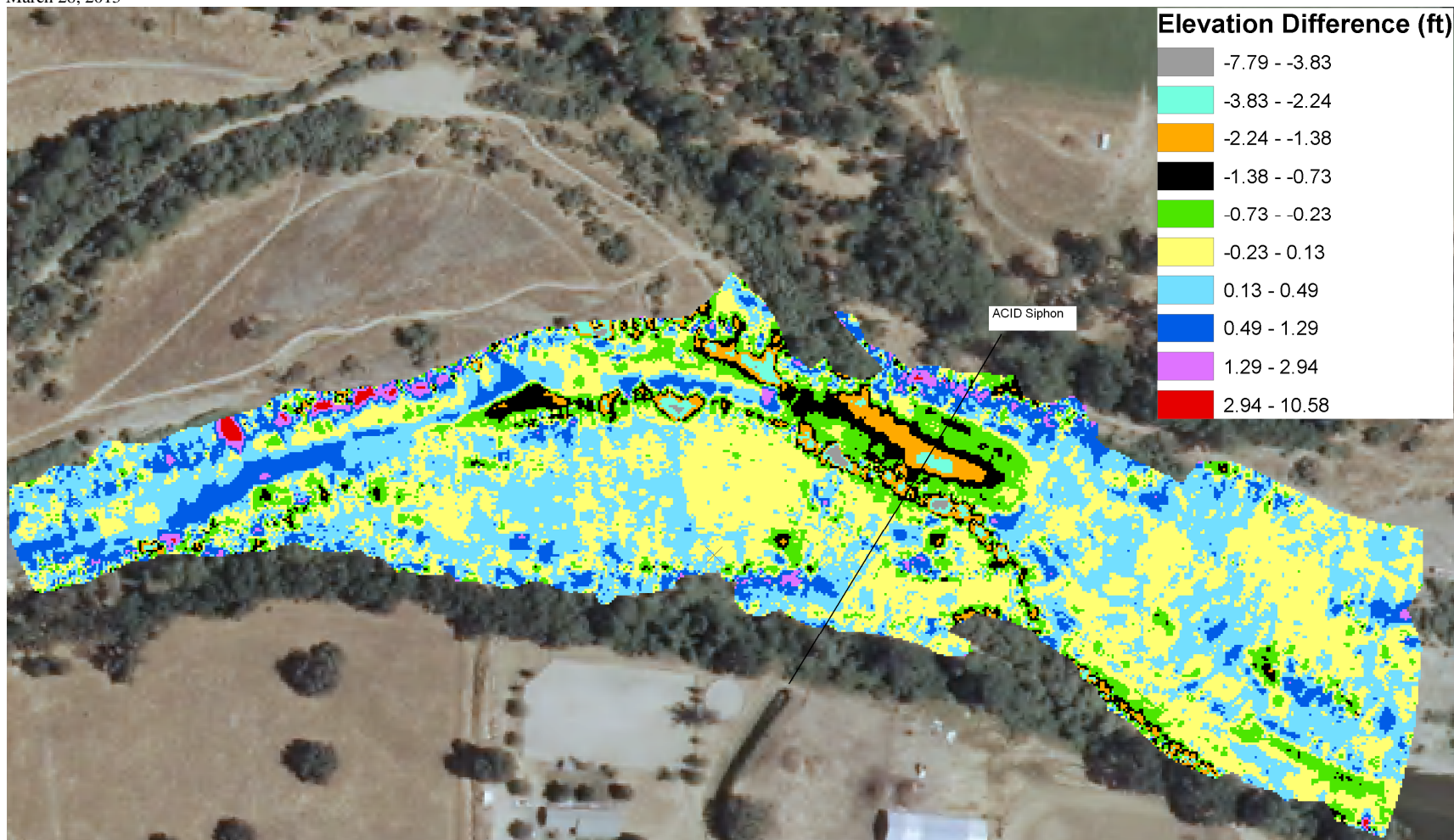


Figure 13
Topographic changes caused by high flows. Positive values indicate aggradation, while negative values indicate erosion.



Figure 14
Longitudinal Thalweg Bed Elevation Profile of the Main Channel and Bypass Channel at the ACID Siphon Site

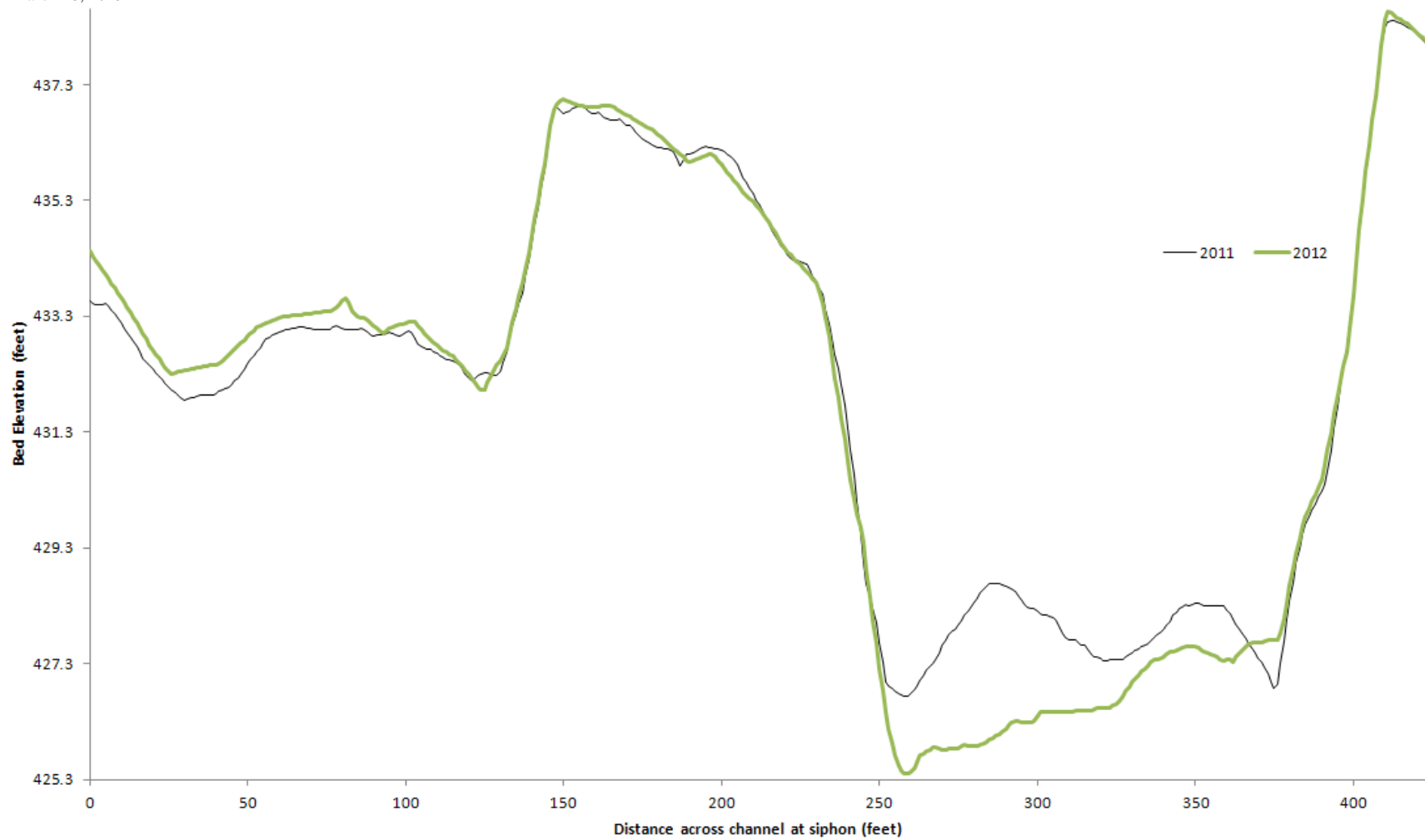


Figure 15
Cross-sectional Bed Elevation Profiles at the ACID Siphon

Discussion

The survey shows the dynamic nature of the restoration site due to the effects of high Cottonwood Creek flows. It should be noted that some of the differences shown in Figures 13 to 15 may be due to differences in the locations of the survey points between the two surveys affecting interpolated values in the two topographic surfaces, rather than to channel changes caused by high flows. If desired, additional displays, such as additional cross-sectional profiles, can be generated from the topography data.

North Fork Cottonwood Creek Habitat Assessment

Methods

An adult spring-run Chinook salmon habitat assessment was conducted on July 30 to August 2 and August 13-15, 2012 on North Fork Cottonwood Creek from RM 10.5 (elevation 837 ft) to 17.2 (elevation 1,438 ft), at the confluence of Jerusalem Creek and North Fork Cottonwood Creek (Figure 16)¹⁵. Adult holding habitat was assessed by collecting the following data for each pool: 1) length and 3-6 widths¹⁶; 2) maximum pool depth and riffle crest depth; 3) water temperature¹⁷; 4) a visual assessment of the percent embeddedness of pool tails; and 5) a visual assessment of the percentage of the pool with each of the following cover types: bedrock ledges, boulder cascades, pocket water, large wood, bubble curtains. In addition, the upstream and downstream end of each pool was recorded with a Garmin GPS unit. We also made a visual assessment of the percentage of spawning gravel in the intervening habitats between pools (i.e. in riffles, runs and glides). Each pool was snorkeled and the number of adult spring-run Chinook salmon and steelhead/rainbow trout, juvenile salmonids, other fish species and California red-legged frog were recorded. Potential upstream passage barriers were assessed using the methods in Gallagher (1999) and Powers and Orsborn (1985), with the following parameters measured: 1) visual classification of the barrier as a fall, chute or cascade; 2) depth of pool below barrier (fish entrance zone) and pool above barrier (fish exit zone); 3) vertical distance from the falls crest to the water surface of the pool below the barrier; 4) depth of penetration of falling water into pool below barrier; 5) horizontal distance from the falls crest to the standing wave in the pool below the barrier; 6) for chutes, the depth of water in the chute; 7) width of barrier; and 8) velocity at top and bottom of barrier. We also measured the discharge of North Fork Cottonwood Creek during each survey, and the flow contributions from Jerusalem Creek and North Fork Cottonwood Creek to the flow of North Fork Cottonwood Creek below their confluence.

¹⁵ River Mile 0 is at the confluence of North Fork Cottonwood and the mainstem of Cottonwood Creek. River Miles increase going upstream.

¹⁶ More widths were measured for longer and less uniform pools.

¹⁷ Instantaneous water temperature measurements were taken in the middle of each pool at the time of the survey using a Taylor Model 5395 digital thermometer.

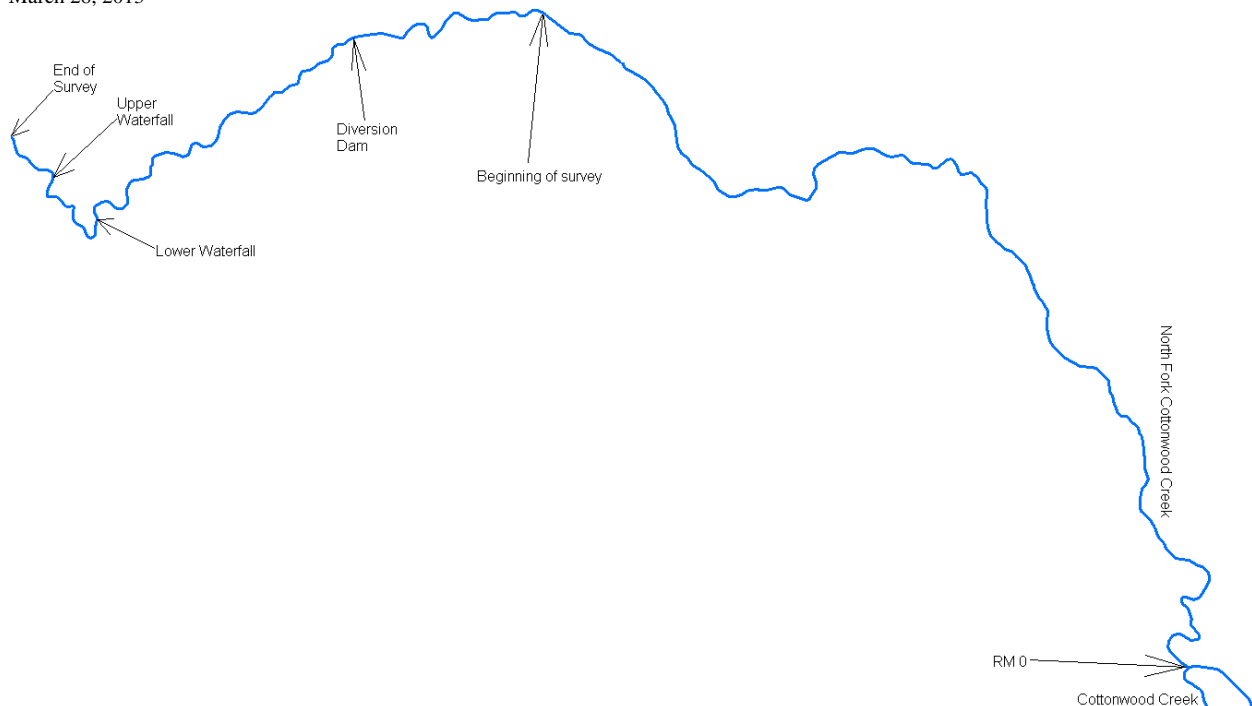


Figure 16
North Fork Cottonwood Study Area

Results

We identified three barriers on North Fork Cottonwood Creek: a 15-foot waterfall at RM 16.6 (Figure 17), a 14-foot waterfall at RM 15.8 (Figure 18) and an seven-foot diversion dam at RM 12.4 (Figure 19). Both the 15-foot and 14-foot waterfalls would be total barriers to both Chinook salmon (with a maximum jump height of 7.9 feet) and steelhead (with a maximum jump height of 10.8 feet). Based on the stream gradient (Figure 20), there are likely additional barriers upstream of the area surveyed. The seven-foot diversion dam would also be a total barrier to both species, based on the criteria that the jump pool needs to be either more than 1.25 times the jump height or at least 8.2 feet deep (Gallagher 1999); there was no jump pool downstream of the diversion dam. Water temperatures exhibited both a diel pattern of variation and an increasing trend going downstream, with water temperatures reaching 73.9 °F at 3:30 PM at the lower waterfall (Figure 21). The discharge of North Fork Cottonwood Creek was 27.9 cfs during the first week of the survey and 20.3 cfs during the second week of the survey. The flow from Jerusalem Creek was 18 percent of the total flow downstream of the confluence of Jerusalem Creek and North Fork Cottonwood Creek.

We sampled 67 pools. We observed four adult, one jack and two yearling spring-run Chinook salmon in the 1.3 miles downstream of the lower waterfall. All but two of these individuals were in the pool just downstream of the lower waterfall. The only fish species observed upstream of the lower waterfall were juvenile rainbow trout, Sacramento pikeminnow and Sacramento suckers, while only juvenile rainbow trout were seen upstream of the upper waterfall. Other



Figure 17
Upstream-most barrier (15 foot waterfall) on North Fork Cottonwood Creek (RM 16.6)



Figure 18
Upstream limit to anadromous fish (14 foot waterfall) on North Fork Cottonwood Creek (RM 15.8)



Figure 19

Downstream-most barrier (seven foot boulder agricultural diversion dam)
on North Fork Cottonwood Creek (RM 12.4) in use at time of study

species observed downstream of the lower waterfall were smallmouth bass (mostly in the lower two miles of the study reach), hardhead, speckled dace and California roach. We also observed one dead Pacific lamprey at RM 11. There was an average of 12 juvenile rainbow trout per pool, ranging in size from approximately 2 to 12 inches in length. Pools comprised 24.7 percent of the length of the sampled reach, with an average area of 2,384 ft², an average maximum depth of 6.0 feet and an average residual pool depth of 4.6 feet. The average cover composition of the pools surveyed was 67 percent bedrock ledge, one percent large wood and three percent bubble curtains. Only six pools had boulder cascade cover and no pools had pocket water. The average pool tail embeddedness was nine percent. The average percentage of spawning gravel in the non-pool portions of the sampled reach was six percent. The amount of spawning gravel in pool tails was not quantified because this parameter was not identified during study development. The spring of 2012 was a below normal water year, although Cottonwood Creek flows during spring-run adult upstream migration (in March through June), reached a maximum of 8,380 cfs.

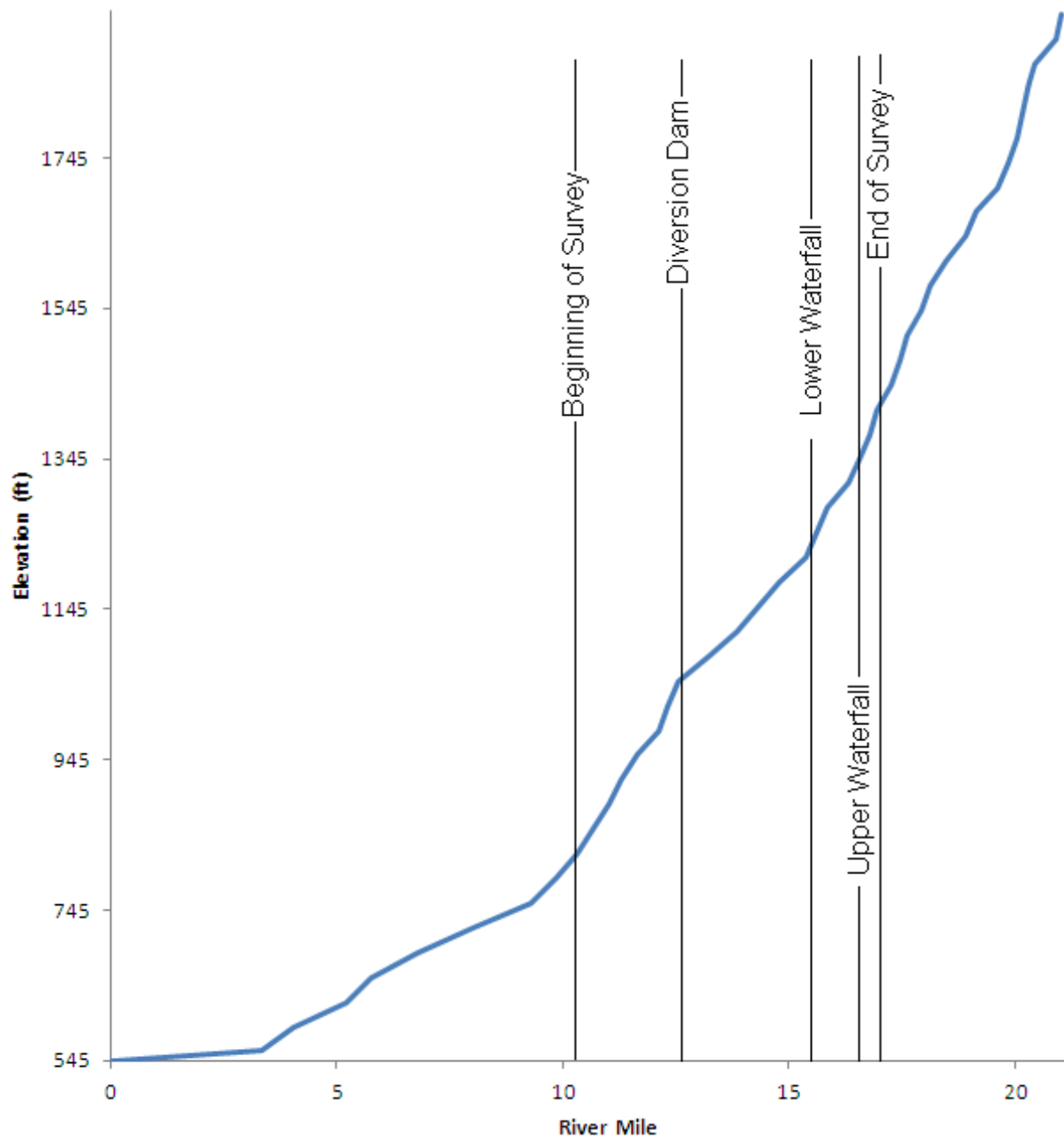


Figure 20
North Fork Cottonwood Creek Profile

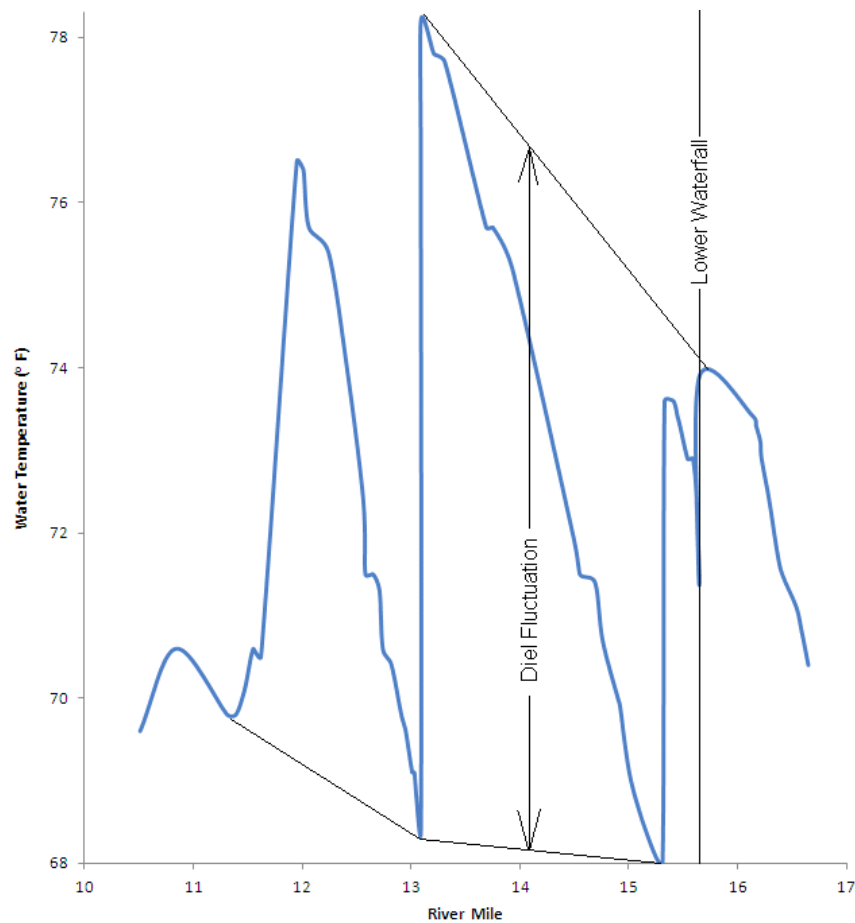


Figure 21
 North Fork Cottonwood Creek Water Temperatures

Discussion

The water temperatures downstream of the lower waterfall in North Fork Cottonwood Creek are likely marginal for adult spring-run Chinook salmon. In comparison, the highest daily mean and daily maximum water temperatures that have been observed within the spring-run holding reach in Butte Creek are, respectively, 74.4 °F and 79.6 °F¹⁸ (unpublished data, Tracy McReynolds, CDFG), while the highest daily maximum water temperature where adult spring-run are observed holding in Beegum Creek, a tributary to Middle Fork Cottonwood Creek, is 76 °F (Doug Killam, CDFG, personal communication). The combination of the lower waterfall excluding adult spring-run from suitable holding habitat above this barrier and high water temperatures below the lower waterfall make it likely that adult spring-run Chinook salmon in North Fork Cottonwood Creek would be restricted in their summer holding habitat to the 1.3 miles downstream of the lower waterfall. The next step in any future assessments of spring-run holding habitat below the lower waterfall would be installing a thermograph to better evaluate

¹⁸ These water temperatures were associated with significant pre-spawning mortality of adult spring-run Chinook salmon (Tracy McReynolds, CDFG, personal communication).

water temperature conditions below this barrier. The data from such a thermograph could be used to calculate maximum weekly average water temperatures. In this regard, Stillwater Sciences (2012) gives a criterion that adult spring-run Chinook salmon holding habitat should not have more than three exceedances of a 66 ° F maximum weekly average water temperature. Given the presence of spring-run Chinook salmon upstream of the diversion dam, we assume that the diversion dam was installed after spring-run Chinook salmon migrated upstream in the spring of 2012. Ensuring upstream passage in spring-time at the diversion dam, which lacks any fish passage facilities, is the highest priority for maintaining spring-run Chinook salmon in North Fork Cottonwood Creek.

Yuba/Feather River Sturgeon Spawning HSC Data Collection

Methods

The California Department of Water Resources (CDWR) placed 254 egg mats to sample for green sturgeon spawning on the Feather River in the vicinity of the Thermalito Afterbay Outlet on April 11 to July 7, 2011. Flows during the sampling ranged from 3,363 to 11,981 cfs. CDWR measured depths but did not measure velocities or substrate sizes at the egg mat locations. Only eight of the mats ended up catching green sturgeon eggs. We were provided with geographic coordinates where the egg mats were placed. On June 25-26, 2012, we attempted to navigate to these locations using our survey-grade RTK GPS and measured depth and velocity at the locations using our ADCP. We also visually classified the substrate at each location where we measured depths and velocities, using the substrate codes in Table 1. We also mapped out depths and velocities throughout the area sampled with the egg mats, using the same methods given above for the deeper areas of the American River gravel sites, and collected data for six PHABSIM transects to use to simulate the velocities that were present during the egg mat sampling. Flows during our data collection were 4,958 cfs.

Results

Windy conditions and complex currents made it difficult to hold on the spawning mat locations. In addition, due to problems with the geographic coordinates, our measurements at specific mat locations did not coincide with the actual horizontal location of the spawning mats. As a result, we did not end up with any substrate data for mat locations. However, in general shallower areas (up to six to eight feet) had approximately 75 percent four to six inch substrate and 25 percent had six to eight inch substrate. Deeper areas had more diverse substrate sizes, ranging from one to three inches up to six to eight inches. We used the mapping of depths and velocities throughout the area sampled with the egg mats (Figures 22 and 23) to interpolate the depths and velocities at the mat locations. Six of the mats with eggs and 13 of the mats without eggs ended up outside of our mapping area due to the problems with the geographic coordinates. However, the six mats with eggs were close to one of our PHABSIM transects, and thus we were able to use the velocities from this PHABSIM transect to determine the velocities and depths at these six mats by using the measured velocity and depth closest to the mat location. The interpolated depth, together with the depth measured during the egg mat sampling, the interpolated velocity,

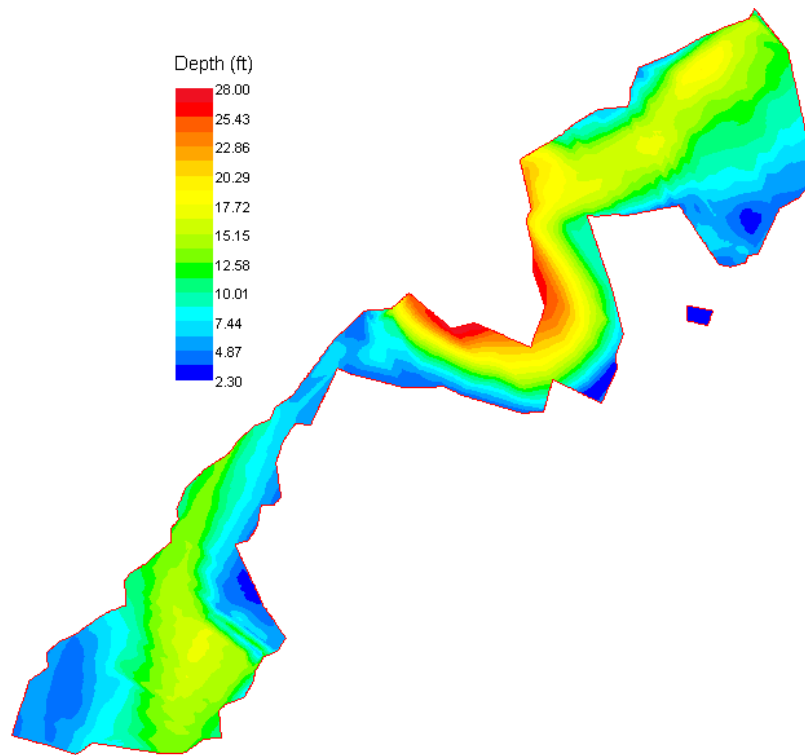


Figure 22
Feather River Depths at Thermalito Afterbay Outlet on June 26, 2012

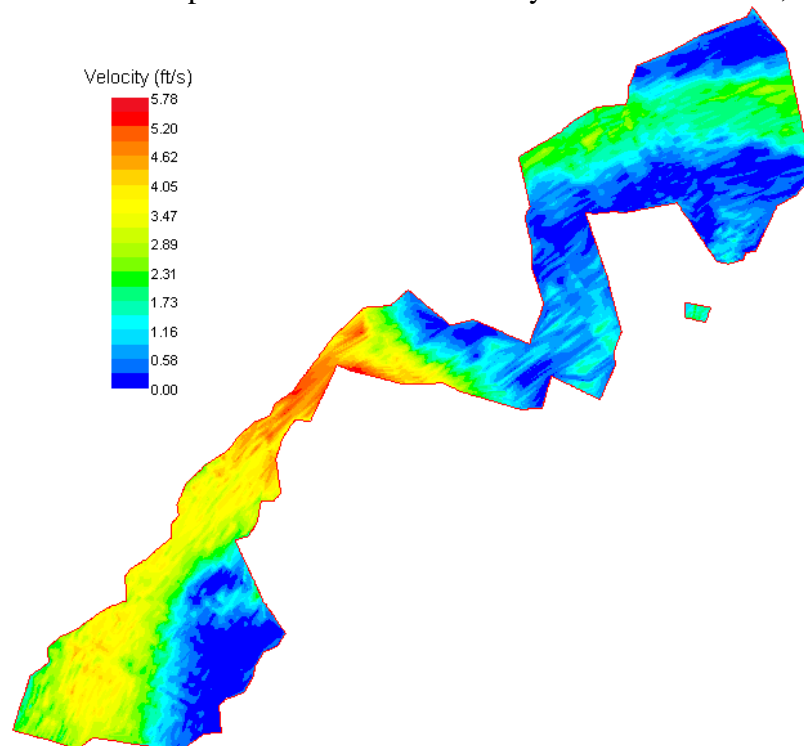


Figure 23
Feather River Velocities at Thermalito Afterbay Outlet on June 26, 2012

and the PHABSIM transects, were used to simulate the velocities that were present during the egg mat sampling. Depths and velocities that were present during the egg mat sampling for the eight mats where green sturgeon eggs were collected (occupied locations) ranged from 5.4 to 18.1 feet and 0.06 to 3.97 feet/sec. Depth and velocities that were present during the egg mat sampling for unoccupied mats (where green sturgeon eggs were not collected) ranged from 3.6 to 29.0 feet and 0.02 to 12.16 feet/sec.

Discussion

This data, in itself, is too small a sample size to develop spawning habitat suitability criteria for green sturgeon. The depths and velocities at the occupied locations fell within the range of depths and velocities at the unoccupied locations, suggesting that green sturgeon were able to select their preferred habitat conditions. We suggest that this data be combined with data from other locations in the Central Valley to develop green sturgeon spawning criteria with a Delphi process, as we did for Sacramento River white sturgeon (U.S. Fish and Wildlife Service 1996).

Clear Creek inSALMO Model Beta Testing

Methods

In 2011, Lang, Railsback and Associates and USDA Forest Service, Pacific Southwest Research Station, developed the Improvement of Salmon Life-Cycle Framework Model (inSALMO) individual-based Chinook salmon model (Railsback et al. 2012) and applied it to two sites on Clear Creek (3A and 3C), using as input hydraulic modeling that we had conducted for these sites. In 2012, the model was extended to more of our sites on Clear Creek. We performed simulation runs for these sites at 2,000, 5,000, 10,000 and 50,000 cfs, so that the inSALMO model could be applied for the entire range of historic flows on Clear Creek.

Results

We completed high flow simulation runs for additional sites; this effort is continuing in FY-2013.

Yuba River Hammon Bar Restoration Project Monitoring

Methods

On June 11-14, 2012, we collected topographic, substrate and cover data at the Hammon Bar riparian restoration site on the Yuba River, using the methods described above for the American River.

Results

We collected a total of 13,603 datapoints. In FY-13, we will combine this data with additional topography data from Greg Pasternack, covering the areas we were unable to sample (primarily a downstream extension). The combined dataset will be used to develop pre- and post-restoration bed and mesh files, using the methods given above for the American River. The computation mesh will be used in River2D, along with water surface elevations from Greg Pasternack's entire Yuba River hydraulic model (as the downstream boundary condition) to model fry and juvenile Chinook salmon and steelhead/rainbow trout habitat over a range of flows, using the habitat suitability criteria from our Yuba River instream flow study, for both pre- and post-restoration conditions. Results will be presented in the FY 2013 annual report.

Cottonwood Creek Baseline Habitat Assessment

Methods

The purpose of this investigation is to collect PHABSIM data on transects previously established by Graham Matthew and Associates (2003), with the resulting PHABSIM transects to be used to quantify the baseline amount of fry and juvenile fall-run Chinook salmon and steelhead/rainbow trout rearing habitat in Cottonwood Creek. The baseline amount of habitat will be used to determine how much habitat will need to be restored in Cottonwood Creek to achieve the doubling goals of AFRP for Cottonwood Creek. Graham Matthews and Associates had 12 transects on Cottonwood Creek downstream of South Fork Cottonwood Creek, nine transects on Cottonwood Creek upstream of South Fork Cottonwood Creek, and two transects on South Fork Cottonwood Creek. We sent letters to the landowners of the properties where the transects were located to get permission for access. For those transects where we got permission for access, we collected the PHABSIM transect data described for the American River, using the same methods, with the following exceptions: 1) all verticals were spaces two feet apart, to allow for the use of an adjacent velocity criteria; and 2) no substrate data was collected, since the parameters used to simulate rearing habitat are depth, velocity, cover and adjacent velocity. Headpins and tailpins were marked on each bank above the 4,400 cfs water surface level for Cottonwood Creek downstream of South Fork Cottonwood Creek, the 2,600 cfs water surface level for Cottonwood Creek upstream of South Fork Cottonwood Creek, and the 1,250 cfs water surface level for South Fork Cottonwood Creek.

On April 30 to May 2, 2012, we conducted mesohabitat mapping for Cottonwood Creek from the confluence of the Middle and North Forks of Cottonwood Creek to the Sacramento River, and for South Fork Cottonwood Creek from Bowman Road to the confluence of South Fork Cottonwood Creek with Cottonwood Creek, marking the ends of each mesohabitat unit with a Garmin GPS unit. Cottonwood Creek was mapped via jetboat, while South Fork Cottonwood Creek was mapped by floating the reach. We had access to the entire length of stream. The GPS data was put in GIS to make polyline shapefiles of the mesohabitat units, which were then used

to calculate the length of each mesohabitat unit. The mesohabitat types used and their definitions are given in Table 3. The mesohabitat mapping will be used to extrapolate from the PHABSIM transects to all of Cottonwood Creek.

Results

We were able to get permission for access for 11 of the transects on Cottonwood Creek downstream of South Fork Cottonwood Creek, three transects on Cottonwood Creek upstream of South Fork Cottonwood Creek, and both transects on South Fork Cottonwood Creek, for a total of 16 transects. In FY 2012, we collected all of the data for five of the 16 transects, and collected most of the data for the remaining 11 transects. We will complete data collection for these remaining transects in FY 2013. In FY 2012, we completed hydraulic calibration for the five transects for which we had finished data collection. In FY 2013, we will conduct hydraulic calibration for the remaining 11 PHABSIM transects, and will generate fry and juvenile fall-run Chinook salmon and steelhead/rainbow trout rearing habitat for all sixteen transects. Habitat will be simulated for the following flow ranges: 1) 15 to 4,400 cfs for Cottonwood Creek downstream of South Fork Cottonwood Creek; 2) 15 to 2,600 cfs for Cottonwood Creek upstream of South Fork Cottonwood Creek; and 3) 0.1 to 1,250 cfs for South Fork Cottonwood Creek. The results of the mesohabitat mapping (Table 4), as well as being used to extrapolate from the PHABSIM transects to the entire reach, were used to randomly select additional PHABSIM transects on Cottonwood Creek upstream of South Fork Cottonwood Creek and on South Fork Cottonwood Creek; data collection and modeling of these transects will occur in FY 2013.

Cottonwood Creek Geomorphic Monitoring

Methods

On August 28-31, 2012, the bed profile of five of the PHABSIM transects was extended beyond the headpins and tailpins, to the original ends of Graham Matthews and Associates (2003) transects, using our survey-grade RTK GPS. We transmitted this data to Graham Matthews and Associates for their use to assess changes in cross-sectional profiles since their data was collected. The number of transects sampled was limited by the length of time required to float Cottonwood Creek due to low flow conditions and the distance at which we were able to receive a radio signal from our RTK GPS base unit.

Results

Our monitoring will allow for a comparison of channel changes for the entire extent of five of the sixteen transects, and for the lower-flow portion of the remaining 11 transects, using data from our PHABSIM data collection. Results will be presented in our FY 2013 annual report, since cross-sectional data collection has not yet been completed for all sixteen PHABSIM transects.

Table 3. Mesohabitat type definitions.

Habitat Type	Definition
Pool	Primary determinant is downstream control - thalweg gets deeper as go upstream from bottom of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface. Depth is not used to determine whether a mesohabitat unit is a pool.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width, below average water velocities, generally associated with tails of pools or heads of riffles, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.
Run	Primary determinants are moderately turbulent and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

Table 4. Mesohabitat composition.

Habitat Type	Glide	Pool	Riffle	Run
Cottonwood Creek downstream of SF Cottonwood Creek	24.06%	28.26%	18.79%	28.90%
Cottonwood Creek upstream of SF Cottonwood Creek	26.48%	32.69%	15.33%	25.50%
South Fork Cottonwood Creek	23.97%	20.12%	14.43%	41.48%

Antelope Creek Geomorphic Monitoring

Methods

Lower Antelope Creek is a distributary system, with flow splitting into Craig, Antelope, and New Creeks and Butler Slough. Stillwater Sciences et al. (2011) identified the nature of the flow splits as a critical piece of information that would be needed to assess upstream fish passage in Lower Antelope Creek. The first flow split, going downstream, is into Craig and Antelope Creeks (Figure 24). The purpose of this investigation was to develop a hydraulic model to determine the flow splits, over a range of Antelope Creek flows. The hydraulic model has two

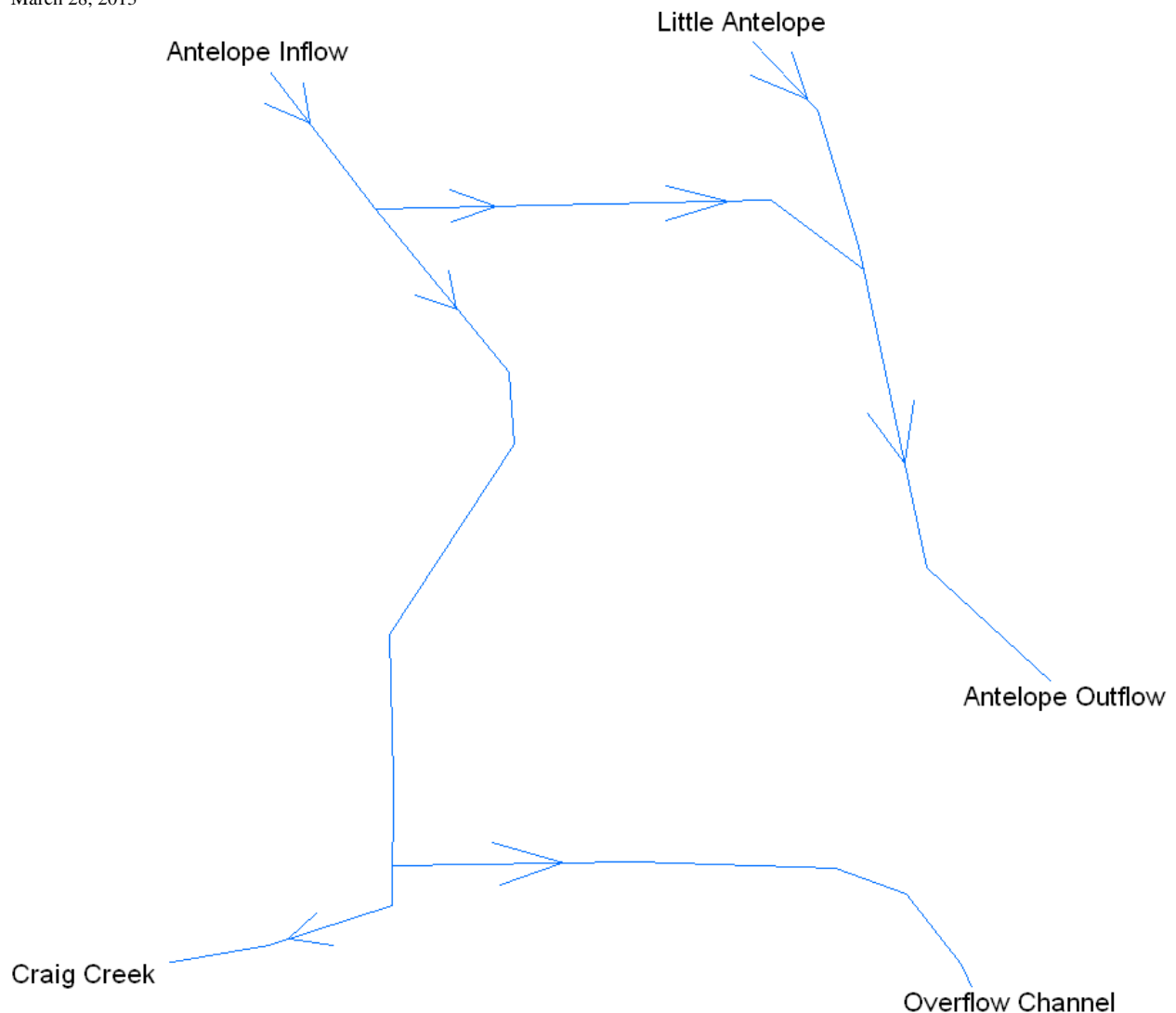


Figure 24
Antelope Creek Flow Split Study Area

inflow boundaries (from Antelope and Little Antelope Creeks) and three outflow boundaries (to Craig and Antelope Creeks and an overflow channel). Data were collected using the same methods given above for the dry and shallow portions of American River gravel sites.

Results

Data collection was completed in FY 2012. Flows (Table 5) and water surface elevations were measured for all five boundaries at three different flows. Hydraulic modeling will be conducted during FY 2013, with results presented in the FY 2013 annual report.

Table 5. Antelope Creek Flow Split Flows (cfs).

Location	4/16-17/12	5/14/2012	7/10/2012
Antelope Creek (Inflow)	148.32	56.01	1.26
Little Antelope Creek	22.61	0.02	0
Antelope Creek (Outflow)	44.86	1.24	0.22
Craig Creek	123.29	54.79	1.04
Overflow Channel	2.78	0	0

American River Screw Trap Site Data Collection

Methods

The purpose of this investigation was to determine the best locations for installing rotary screw traps in the American River at Watt Avenue. Depths and velocities were mapped on the American River at Watt Avenue on June 6, 2012, at a flow of 1,900 cfs, using the same methods given above for the deeper areas of the American River gravel sites.

Results

The mapping of the depths and velocities (Figures 25 and 26) showed the best locations for screw traps would be at the upstream end of the island on the north channel and at the downstream end of the island on the south channel.

REFERENCES

- Gallagher, A.S. 1999. Assessing natural and small artificial barriers. Pages 136-141 in M.B. Bain and N.J. Stevenson, editors. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.
- Gard, M. 1998. Technique for adjusting spawning depth habitat utilization curves for availability. *Rivers*: 6: 94-102.
- Graham Matthew and Associates. 2003. Hydrology, geomorphology, and historic channel changes of Lower Cottonwood Creek, Shasta and Tehama Counties, California. Prepared by Graham Matthews and Associates, Weaverville, California for National Fish and Wildlife Foundation, San Francisco, California. CALFED Bay-Delta Program Project #97-N07 Final Report.

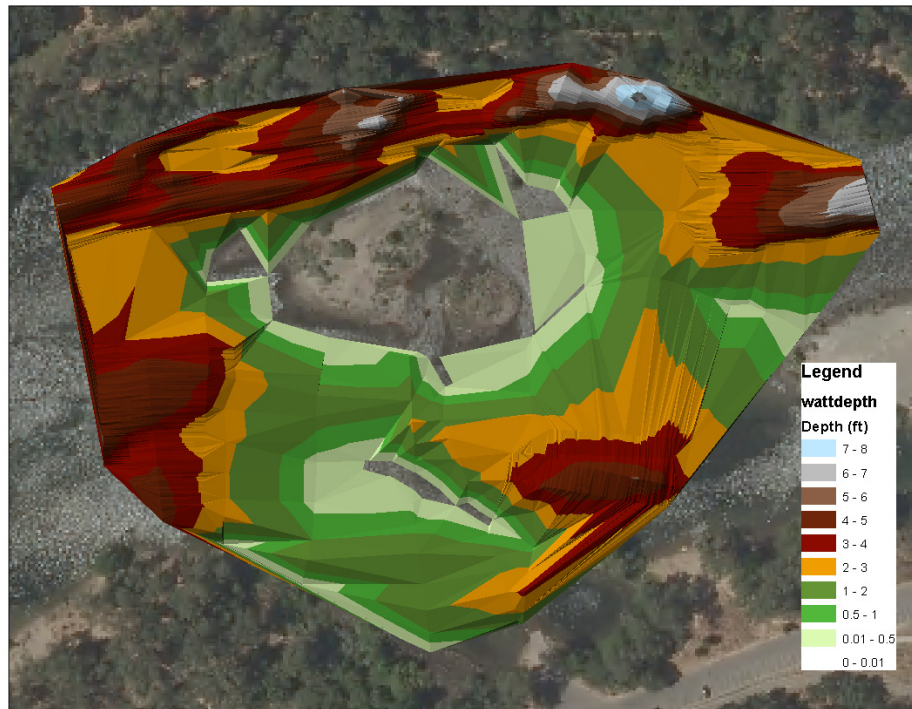


Figure 25
American River Depths at Watt Avenue

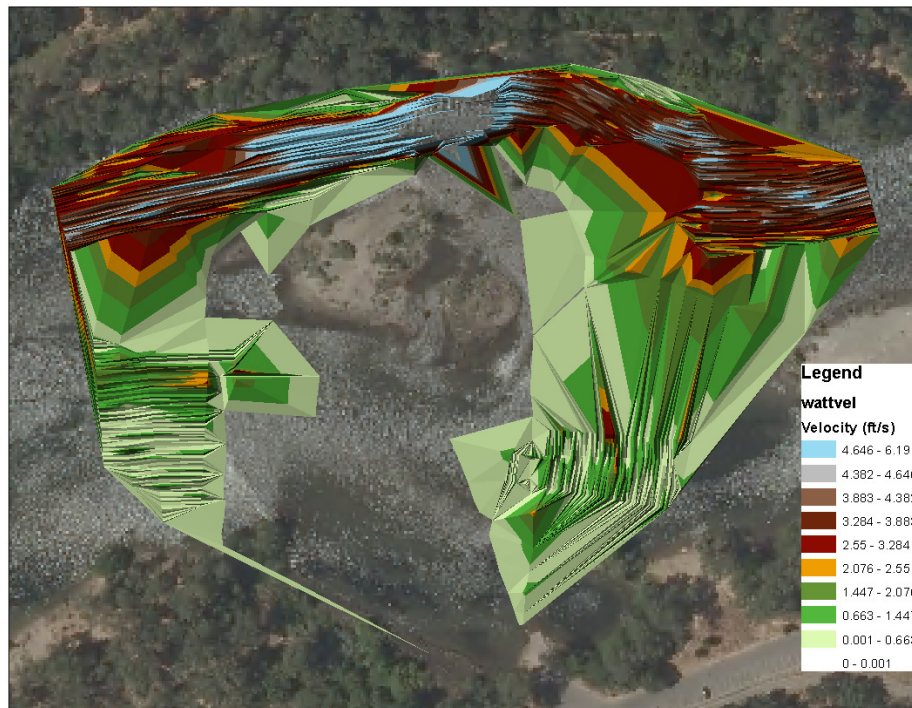


Figure 26
American River Velocities at Watt Avenue

- Milhous, R.T., M.A. Updike and D.M. Schneider. 1989. Physical habitat simulation system reference manual – version II. Instream Flow Information Paper No. 26. Biological Report 89(16). U.S. Fish and Wildlife Service: Fort Collins, Colorado.
- Power, P.D. and J.F. Orsborn. 1985. Analysis of barriers to upstream fish migration. An investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. Albrook Hydraulics Laboratory, Washington State University, Pullman, WA.
- Railsback, S.F., B.C. Harvey, and J.L. White. 2012. inSALMO Version 1.0: Model Improvements and Demonstration Application to Chinook Salmon Spawning, Incubation, and Rearing in Clear Creek, California. Revised final report prepared by Lang, Railsback & Associates and USDA Forest Service, Pacific Southwest Research Station for the US Bureau of Reclamation, Mid-Pacific Regional Office. January 30, 2021. 305 pp. with appendices. Available at: http://www.fws.gov/sacramento/Fisheries/Instream-Flow/fisheries_instream-flow_inSalmo.htm
- Stillwater Sciences, Tehama Resource Conservation District, and M. Kondolf. 2011. Assessment of hydrology and geomorphology related to fish passage in Lower Antelope Creek. Draft Report. Prepared by Stillwater Sciences, Arcata, California; Tehama Resource Conservation District, Red Bluff, California; and University of California, Berkeley for U.S. Fish and Wildlife Service National Fish Passage Program, Red Bluff, California.
- Stillwater Sciences. 2012. Modeling habitat capacity and population productivity for spring-run Chinook salmon and steelhead in the Upper Yuba River watershed. Technical Report. Prepared by Stillwater Sciences, Berkeley, California for National Marine Fisheries Service, Santa Rosa, California.
- U.S. Bureau of Reclamation. 2012. Stanislaus River discharge-habitat relationships for rearing salmonids. U.S. Bureau of Reclamation: Denver, CO.
- U.S. Fish and Wildlife Service. 1996. Sacramento River white sturgeon spawning criteria. U.S. Fish and Wildlife Service: Sacramento, CA.
- U.S. Fish and Wildlife Service. 2006. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook salmon and steelhead in the Sacramento River between Keswick Dam and Battle Creek. U.S. Fish and Wildlife Service: Sacramento, CA.

USFWS, SFWO, Restoration and Monitoring Program
FY 2012 Annual Report
March 28, 2013

U.S. Fish and Wildlife Service, California Department of Fish and Game and Pacific States
Marine Fisheries Commission. 2011. Central Valley Project Improvement Act
Anadromous Fish Restoration Program Annual Report - Redd Dewatering Pilot Study,
AFRP-N02-10 Upper Sacramento River Year 1: October 1, 2010 to March 31, 2011.
U.S. Fish and Wildlife Service: Red Bluff, CA.